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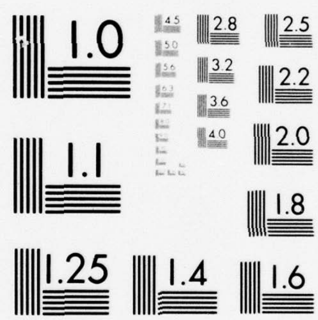

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CAPACITY STUDIES OF WINFIELD LOCKS KANAWHA RIVER, WEST VIRGINIA

by

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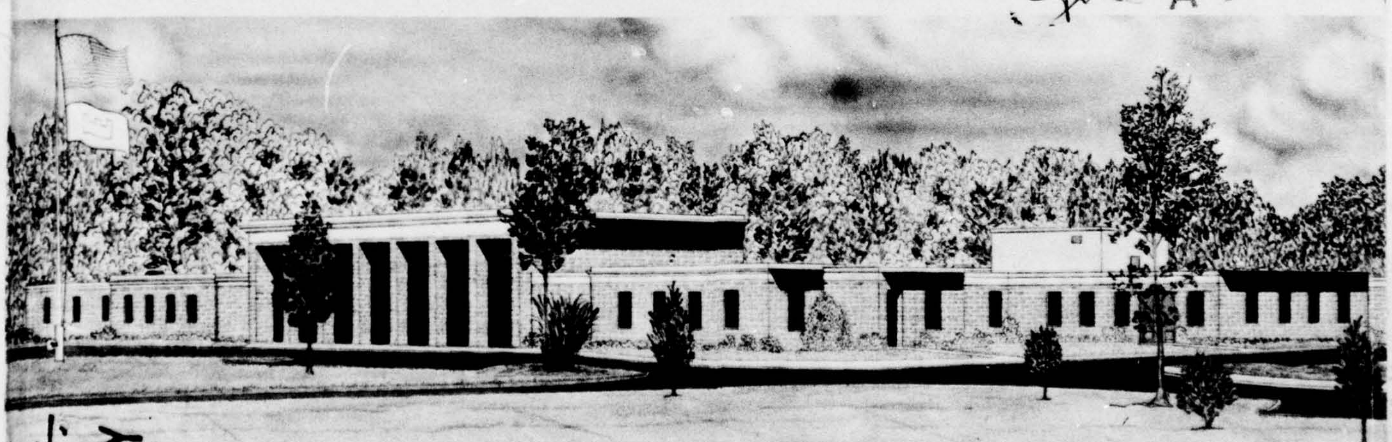
February 1977
Interim Report



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The Winfield lockage facilities currently consist of two 360-ft x 56-ft chambers with a normal lift of 28 ft. With the increasing traffic on the Kanawha River, these facilities are no longer adequate to serve the towing industry using this portion of the inland waterway system. Excessive delays now occur at Winfield and if the predicted traffic growth materializes during the next 10 or 15 years without action being taken by the Corps to address the problem, transfers of traffic movements to other more costly modes of

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transportation will result. Accordingly, studies were conducted to determine the capacity of the existing lockage facilities and to evaluate possible solutions for increasing this capacity through the use of alternative operating policies and rules that have been considered to be beneficial at other lock sites. Using the two simulation models, TOWGEN and WATSIM IV, the following four alternative operating policies were simulated to determine their respective effects on the capacity of Winfield and the delays to be expected should such policies be possible: --

(a) First In-First Out (FIFO) Unrestricted;

(b) FIFO Unrestricted with a 10 percent reduction in lockage component times;

(c) FIFO Ready-to-Serve; and

(d) 3 Up-3 Down, Unrestricted.

These operating policies are discussed in detail in the report. Input data for the models were collected through the Performance Monitoring System (PMS) of the Inland Navigation Systems Analysis (INSA) program. The report includes discussions of model calibration and the criteria employed to analyze the capacity of the lockage facility based on the best available projections of future tonnage levels. Numerous capacity curves were developed to show the relationship between increasing commodity tonnages, tow delays, and lock utilization.

PREFACE

The study reported herein was performed by the U. S. Army Engineer Waterways Experiment Station (WES) for the U. S. Army Engineer District, Huntington. WES used computerized simulation models in conducting the investigation of the Winfield Locks' potential to serve future traffic levels. The Huntington District (ORHED-PE) provided essential prototype data and assistance in analyzing and reducing these data.

Completion of the planned Winfield Locks capacity studies was suspended as a result of a critical requirement to reanalyze the proposed replacement of the Gallipolis Locks. As a result, only the first objective of the Winfield studies is reported, i.e., the determination of capacity relative to the existing facilities and several alternative operating policies.

The investigation was conducted by Dr. L. L. Daggett and Mr. R. W. McCarley of the Mathematical Hydraulics Division (MHD), under the general supervision of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, and Mr. M. B. Boyd, Chief, MHD. The report was prepared by Mr. McCarley with technical guidance and input from Dr. Daggett. Special assistance and advice was provided by ORHED-PE during the course of the investigation. Acknowledgement is made to Messrs. Alan Elberfeld, Ron Mead, David Weekly and Ed Stone of the Huntington District for their cooperation and assistance at various times throughout the investigation.

Directors of WES during the conduct of this investigation and preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

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CAPACITY STUDIES OF WINFIELD LOCKS, KANAWHA RIVER WEST VIRGINIA

PART I: INTRODUCTION

Background

1. The Winfield lockage facilities, located near Winfield, WV, currently consist of two 360-ft x 56-ft chambers with a normal lift of 28 ft. Since many of the tows using these locks are much longer than the chambers, they necessarily must break into sections for lockage. In addition, the river configuration of many tows would probably be much wider than at present if the lock chambers were wide enough to accommodate them, as it is known that short, wide tows can more easily navigate tight bends as are found on the Kanawha River. Three- and four-cut lockages are not uncommon and the maximum number of cuts now reach as high as eight. The breaking and remaking of large tows within an undersized lock chamber inherently requires long processing times and often results in the excessive delay of tows waiting to be serviced. The results of such delays and the accompanying long waiting lines at the Winfield locks are the inefficient use of men and equipment, rapidly escalating costs for the shipper, less reliability in the receipt of commodities on time, and hence increased storage costs to the user as stockpiling is required. If the delays to movements become great enough, transfers of traffic movements to other more costly modes of transportation will result.

2. The traffic passing through the Winfield locks is predicted to grow dramatically during the next 15 years. Detailed commodity growth projection studies have been completed for 1980 and 1990, revealing 65% and 125% increases, respectively, over and above the tonnages reported in 1975. Such growth will undoubtedly tax the lockage capabilities of the current facilities at Winfield. With tonnage growth of this magnitude expected in the near future, the Winfield capacity studies reported

herein were initiated in March 1976 to estimate the associated increase in delays and the resulting costs to the towing industry and to develop information required for estimating the capacity of the present locks and the proposed replacement alternatives. These studies, though not complete at this writing, will provide essential knowledge required in planning for the proper expansion of locking capabilities at Winfield.

Objectives

3. The first objective of the Winfield studies was to determine the capacity of the existing lockage facilities and to evaluate possible solutions for increasing this capacity through the use of alternative operating policies and rules that have been considered to be beneficial at other lock sites. The initial overall objectives of the work also included the evaluation of proposed alternative structural improvements if, as a result of the capacity studies, such improvements were considered necessary for the continued efficient operation of the locks. The final objective at the outset of these studies was to evaluate the effect of the current or any proposed replacement locks on the waterway system. The system-wide analysis was to allow for the determination of costs and benefits to the towing industry and their customers resulting from more efficient shipping and improved transit times throughout the waterway.

4. Completion of the planned Winfield capacity studies has been suspended as a result of a critical requirement to reanalyze the proposed replacement of the Gallipolis Locks. The decision was made during the last week of June 1976 to suspend work on the Winfield studies at a logical stopping point and to then redirect all resources to the more urgent Gallipolis study. As a result, only the first objective of the Winfield studies will be accomplished at this time, i.e., the determination of capacity relative to the existing facilities and several alternative operating policies, some of which would undoubtedly require major

improvements to the approaches and/or the availability of several switchboats to assist in the lockage operations.

Scope

5. Therefore, the scope of the study has been limited to analyzing the capacity of the existing Winfield locks. Tonnage projections representing a "most likely" growth in traffic were available for the years 1980 and 1990. Thus, only one set of tonnage projection data were used during the study. The characteristics (general configuration) of the tow fleet currently using Winfield were assumed to remain unchanged in the future, though it was recognized that larger tows from the Ohio River may someday use the Kanawha River. The original scope included an analysis of changes in the tow characteristics and makeup but had to be suspended at this time for the reasons given above.

6. The following four alternative operating policies were simulated to determine their respective effects on the capacity of Winfield and the delays to be expected should such policies be implemented:

- a. First In-First Out (FIFO) Unrestricted
- b. FIFO Unrestricted
  with a 10% reduction in lockage component times
- c. FIFO Ready-to-Serve
- d. 3 Up-3 Down, Unrestricted

The above operating policies will be discussed in further detail later in the report.

Approach

7. Simulation modeling methodology was used to evaluate the locks at Winfield. This type of modeling has been used in the past to analyze the lock replacement and improvement projects being proposed for the Illinois Waterway, the Upper Mississippi and the proposed Red River

waterway. Simulation modeling techniques were also applied in a detailed analysis of Locks and Dam 26, Mississippi River, and they are currently being used to analyze the effects of the replacement of existing locks on the Black Warrior River System.

8. The particular simulation model used in these studies was developed for the Corps of Engineers by Pennsylvania State University and extensively modified and expanded by the WES during the past several years. The model consists of two computer programs named TOWGEN (tow generator) and WATSIM (waterway simulator), which are described in detail in "A New Generalized Waterway Simulator: WATSIM IV."[1] A general discussion of the model is given later in this report. The most recent approach to using the simulation model for determining the capacity of a set of locks has been discussed in a recent paper entitled, "Determination of Lock Capabilities Using Simulation Modeling,"[2] presented at the First International Waterborne Transportation Conference in October 1975. The same model was slightly modified for use in this study to determine the capacity of the existing Winfield Locks and to evaluate any possible alternative lock operating policies.

9. In order to model the waterway traffic at Winfield, information had to be obtained regarding the traffic using the locks, the times required to process vessels, the commodities passing through the locks, and the types of lockages occurring. The data being collected as part of the Performance Monitoring System (PMS) were utilized as the source of the required information.

PART II: THE WATSIM/TOWGEN MODEL

Brief Description of the Simulation Model: TOWGEN/WATSIM

10. As mentioned in Paragraph 8, the simulation model used in this study consisted of two separate computer programs called TOWGEN and WATSIM. TOWGEN is a tow generation program that combined the commodity movement pattern and the tow equipment and flotilla description to develop a randomly generated list of simulated tows to be moved through the waterway system being tested. This tow list contains a description of the characteristics of each tow, the origin and destination of each movement, and the time of entry into the system. The tows are generated so that all the commodity movements required are started during the simulated time period. The tows are generated in such a manner as to assure that a balance of equipment exists throughout the system, i.e., that empty barges are moved to the locations where they are required for the movement of goods.

11. Through the use of TOWGEN, the towing industry's requirements or demands for use of the waterway being analyzed may be developed for input to the waterway simulator, WATSIM. WATSIM reads the list of tows generated by TOWGEN and inserts the simulated tows at the appropriate time into the traffic flow on the waterway at its point of origin. WATSIM then moves each tow from its originating point to its destination in a series of steps covering each segment of the simulated waterway. As each tow is moved, statistics concerning the trip and the waterway facilities used are accumulated. These statistics provide a measure of the waterway's effectiveness in handling the traffic demands placed upon it and the time required to transit the waterway between various points. This transit time may then be interpreted into a cost of transport through the application of tow operating costs per unit of time.

12. The simulation process used by WATSIM is called event modeling. The various activities required to accomplish the task being modeled are represented by a series of events. Because the time to accomplish these events and, hence, the entire task is the critical parameter, each event is represented by WATSIM as a period of elapsed time. Because these times are stochastic and not deterministic, they are described by frequency distributions and functional representations. The modeling process thus involves the logical combination of the events required to move a tow from its origin to its destination, accounting for the interaction of the tows at commonly shared facilities.

13. Simulation modeling involves the use of simplified representations of the real-world activities involved in the modeled situation. The degree of simplification allowed in the description of any event depends upon the purpose of the simulation and significance of that event to the process being simulated. WATSIM has been primarily used in the past to evaluate lock replacement or expansion requirements and scheduling. Therefore, the modeling of these events is quite detailed and well developed.

WATSIM Modifications

14. Modifications were made to the WATSIM program (written in FORTRAN) to enable the printing of all model output required for capacity analysis on one table (Table 13, Composite Lock Statistics) and to more accurately compute the utilization of the lock chambers. The major modification involved the creation of a summary output subroutine that produces the desired statistics. All information now printed on Table 13 (see Figure 1) was formerly available in Tables 3A, 3D, 4, and 12. The new modification to the program allows the data required for capacity determination to be obtained from only one printed page rather than the four pages previously required, thus reducing the printing time for each run. These data may be placed on disc or tape files at the

central site in addition to being printed at a remote batch site. At the conclusion of each run, all output tables (1-13) are printed for the entire simulation period (one 30-day month for this study). The chamber utilization (percent of time chamber is used) by direction was included in the new Table 13. The revised method for computing utilization is considered more accurate and realistic than previously employed because now the model considers the actual length of time the chamber is used over the simulation period, rather than merely the tow processing time. No changes were made to the way the model processes tow movements during a simulation run. Actual program coding changes have been documented in a memorandum which can be obtained either from the Waterways Experiment Station (ATTN: WESHM) or the Huntington District (ATTN: ORHED-PE).

15. The data in Table 13 (Figure 1) are self-explanatory. The upper portion of Table 13 presents useful data for each chamber; the lower portion displays other important data by lock. The Run Identification Number ("0001M01WFU75" in Figure 1), which is explained in Appendix A, simulation time (47520 minutes in the figure), and the number of chambers and locks are shown as header information on each printed page. All output information contained in the printed table is also written to a file at the central computer site. This includes data for every intermediate output simulation time interval, as provided in the printouts. The file may then be accessed by post-WATSIM processing programs to provide data for various analyses. A short program to retrieve the data file on cards at the remote site at WES has also been written. It reads the data on the file, changes formats in some cases, then punches the data on cards so that the files at the central site can be purged for use by others. Each card contains the RUN ID Number, the time of data sample, the lock name, chamber designation (e.g., 1, 2), and a sequence number in addition to the various data items in Table 13.

0001M01MFU75 47520 2 1

TABLE NUMBER 13
COMPOSITE LOCK STATISTICS

		WINFLD CHMB 1	WINFLD CHMB 2
NO. OF SINGLE LOCKAGES	DN	6	10
	UP	6	4
	TOTAL	12	14
NO. OF DOUBLE LOCKAGES	DN	21	44
	UP	22	25
	TOTAL	43	69
NO. OF TRIPLE LOCKAGES	DN	54	32
	UP	63	32
	TOTAL	117	64
NO. OF SETOVER LOCKAGES	DN	3	0
	UP	0	3
	TOTAL	3	3
NO. OF MULTI-TOW LOCKAGES	DN	0	0
	UP	0	0
	TOTAL	0	0
NO. OF OPEN-PASS LOCKAGES	DN	0	0
	UP	0	0
	TOTAL	0	0
TOTAL NO. OF LOCKAGES	DN	84	86
	UP	91	64
	TOTAL	175	150
TOTAL NO. OF BARGES	DN	341	317
	UP	400	248
	TOTAL	741	565
TOTAL TOW PROCESSING TIME	DN	9674	7349
	UP	11951	7130
	TOTAL	21625	14479
PERCENT UTILIZATION	DN	22.98	17.86
	UP	28.26	16.95
	TOTAL	51.25	34.81

		WINFLD
TOTAL NO. OF TOWS	DN	170
	UP	155
	TOTAL	325
NO. OF MULTI-LOCKAGE TOWS	DN	0
	UP	0
	TOTAL	0
NO. OF TOWS DELAYED	DN	52
	UP	50
	TOTAL	102
TOTAL NO. OF LOADED BARGES	DN	317
	UP	402
	TOTAL	719
TOTAL NO. OF EMPTY BARGES	DN	341
	UP	246
	TOTAL	587
TOTAL TONNAGE	DN	336000
	UP	547280
	TOTAL	883280
TOTAL DELAY TIME (MIN)	DN	3046
	UP	2976
	TOTAL	6022
AVG DELAY FOR TOWS DELAYED	DN	59
AVG DELAY FOR TOWS PASSING	DN	18

THE CURRENT SIMULATION TIME IS 47521 NUMBER OF MINOR ERRORS THUS FAR 0 LENGTH

Figure 1: Composite Lock Statistics (Table 13)

Computer Facilities Used

16. The CDC 6600 computer facilities located at the U. S. Army Mobility Engineering Research and Development Center (MERDC), Ft. Belvoir, VA, were used to make all simulation runs. Access to this computer system was made through the COPE terminal located at the WES.

PART III: ANALYSIS OF WINFIELD PROTOTYPE LOCKAGE DATA

General

17. The July 1975 prototype data collected under the PMS program provided the primary source of input data required by the TOWGEN/WATSIM model. Lockage data for three additional months (May, Sept, and Dec) were used in formulating average statistics for comparison with the July data and for determining seasonal effects on lockage and traffic characteristics. In addition, December 1975 PMS data were used during the calibration phase of the study, as will be discussed in Part IV of this report. The over 300 tow lockages recorded during July 1975 were considered to be an adequate sample size, and based on comparisons with other available data, July proved to be representative of the other months.

Barge Type Determination

18. A number of different barge types and sizes pass through Winfield. A careful study of the barge types using Winfield, as reported for July, resulted in the list of predominant types shown in Figure 2. Since integrated barges vary in size, a rule for classifying them by barge type had to be established. Considering that one of the alternative replacement locks proposed for study is 800 ft in length, a barge size of 265 ft in length was selected as the breakpoint for barges classed in the IC260 and IC300 classes. Barges between 201 ft and 265 ft in length can be placed in an 800-ft lock in three-barge long sections. No particular problem was encountered in type classifying the IP240 and IP260 type barge passing through Winfield during July.

Bivariant Density Distribution of Tow Types

19. The next step in the data analysis was to prepare a bivariant density distribution of tows classified according to the 10 predominant

Barge Type	Description
R BULK	175' x 26' Open & Covered Hopper; Bulk Commodities
J BULK	195' x 35' Open & Covered Hopper; Bulk Commodities
IP 240	240' x 50' Integrated Petroleum Barges
IP 260	260' x 53' Integrated Petroleum Barges
J TANK	195' x 35' Tank Barges (Petroleum & Chemical)
S CHEM	200' x 50' Chemical Barges
IC 260	260' x 53' Integrated Chemical Barges
IC 300	300' x 52' Integrated Chemical Barges
CEM 278	278' x 50' Cement Barges
SGC 110	100' to 125' x 26' Sand, Gravel, Clay, and Rock Barges

Figure 2 - Predominant Winfield Barge Types (Approx. Dimensions Indicated)

barge types. These distributions consist of a count of tow types by horsepower and number of barges. Table 1 is a representation of these counts in the format required by the model and shows the percent of tows in each horsepower/size class by barge type. A number of mixed barge tows were classified according to the dominant barge type and included in the counts. When no dominant barge type was present in a mixed barge tow, such tows could not be included in these counts. These distributions were checked against the 4-month average distributions and found to be similar.

Current Lockage Types at Winfield

20. For each barge type classification used in the simulation model and each tow size based on the number of barges in the tow, a standard tow dimension (length and width) and type of lockage that would normally be expected at the existing Winfield Locks was developed. This was largely a hand computation task based on the average barge size and towboat length and current flotilla configurations. It was observed in the prototype data that all tows consisting of barges larger than standard barges (175 ft x 26 ft) were configured one barge wide; thus, this configuration was used in computing flotilla dimensions and lockage types. The assumed tow sizes and lockage types for the existing Winfield locks are shown in Table 2. Note, however, that WATSIM at present models multi-cut lockages that require more than two cuts by randomly drawing processing times from a single distribution of time, i.e., no consideration is given to the size of the tow being processed. When the sampling period includes a representative sample of the lockages occurring at the locks, the proportion of times randomly drawn from the processing time distribution will be the same as the proportion of lockages having 3, 4, 5, etc. cuts. The effect of this is that, as the fleet characteristics change, the time distribution for the lockages being used must be adjusted to reflect the changing proportions of processing times of these

UTILITY.1 004 WINFIELD STUDY 1975 TRAFFIC

FREQUENCY DISTRIBUTION OF EXPECTED TOW CHARACTERISTICS

REACH 1

NO. OF BARGES PER TOW	TOWBOAT HORSEPOWER 125	375	750	1250	1750	2250	2750	3500	4500	0	TOTAL
TOW TYPE 1											
1	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
2	0.0	1.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	5.0
3	0.0	1.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
4	0.0	1.0	3.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	6.0
5	0.0	0.0	17.0	0.0	0.0	0.0	1.0	2.0	0.0	0.0	20.0
6	0.0	0.0	18.0	0.0	1.0	0.0	6.0	1.0	0.0	0.0	26.0
7	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
8	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
9	0.0	0.0	0.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	3.0
10	0.0	0.0	0.0	4.0	12.0	1.0	9.0	0.0	0.0	0.0	26.0
TOTAL PERCENT	0.0	3.0	49.0	10.0	15.0	2.0	18.0	3.0	0.0	0.0	100.0
TOW TYPE 2											
1	0.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
2	0.0	9.0	16.0	2.0	2.0	0.0	0.0	0.0	3.0	0.0	32.0
3	0.0	13.0	2.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	18.0
4	0.0	0.0	18.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0	33.0
5	0.0	0.0	5.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	11.0
TOTAL PERCENT	0.0	24.0	43.0	7.0	23.0	0.0	0.0	0.0	3.0	0.0	100.0
TOW TYPE 3											
1	0.0	0.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	25.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	38.0	0.0	25.0	0.0	0.0	12.0	0.0	75.0
TOTAL PERCENT	0.0	0.0	0.0	38.0	25.0	25.0	0.0	0.0	12.0	0.0	100.0
TOW TYPE 4											
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	18.0	0.0	9.0	0.0	0.0	0.0	27.0
4	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	64.0	0.0	73.0
TOTAL PERCENT	0.0	0.0	0.0	9.0	18.0	0.0	9.0	0.0	64.0	0.0	100.0

TABLE 1 TOW SIZE-HORSEPOWER DISTRIBUTIONS BY TOW TYPE
(Sheet 1 of 2)

TOW TYPE 5

1	0.0	9.0	5.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	23.0
2	0.0	8.0	17.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	27.0
3	0.0	17.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	22.0
4	0.0	11.0	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.0
TOTAL PERCENT	0.0	45.0	39.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

TOW TYPE 6

1	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0
2	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	9.0	46.0	0.0	0.0	0.0	0.0	0.0	0.0	55.0
5	0.0	0.0	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0
6	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0
TOTAL PERCENT	0.0	0.0	9.0	91.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

TOW TYPE 7

1	0.0	0.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0
2	0.0	4.0	4.0	0.0	16.0	0.0	4.0	4.0	0.0	0.0	32.0
3	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
4	0.0	0.0	20.0	4.0	32.0	0.0	0.0	0.0	0.0	0.0	56.0
TOTAL PERCENT	0.0	4.0	28.0	12.0	48.0	0.0	4.0	4.0	0.0	0.0	100.0

TOW TYPE 8

1	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0
2	0.0	0.0	14.0	0.0	5.0	0.0	5.0	29.0	0.0	0.0	53.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	0.0	14.0
4	0.0	0.0	19.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	24.0
TOTAL PERCENT	0.0	9.0	33.0	0.0	10.0	0.0	5.0	43.0	0.0	0.0	100.0

TOW TYPE 9

1	0.0	0.0	0.0	93.0	0.0	0.0	0.0	0.0	0.0	0.0	93.0
2	0.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0
TOTAL PERCENT	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

TOW TYPE 10

1	12.0	0.0	0.0	23.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0
2	0.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0
3	0.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	12.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0
TOTAL PERCENT	12.0	13.0	50.0	24.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

TABLE 1 (Sheet 2 of 2)

TABLE 2

LOCKAGE TYPES BY TOW SIZE AND BARGE TYPE
EXISTING 360 x 56 ft LOCKS AT WINFIELD

No. Barges	Tow Length* Ft	Tow Width Ft	Pusher Length Ft	Lockage Type**
		TOWS WITH "R BULK" BARGES (Barge Size = 175 x 26 ft)		
1	240	26	65	55
2	240	52	65	1
3	415	52	65	44
4	415	52	65	2
5	590	52	65	2
6	590	52	65	2
7	785	52	85	3
8	785	52	85	3
9	990	52	115	3
10	990	52	115	3
		TOWS WITH "J BULK" BARGES (Barge Size = 195 x 35 ft)		
1	265	35	70	1
2	460	35	70	2
3	675	35	90	3
4	890	35	110	4
5	1105	35	130	5
		TOWS WITH "IP 240" BARGES (Barge Size = 240 x 50 ft)		
1	340	50	100	1
2	580	50	100	2
3	840	50	120	4
4	1110	50	150	5
		TOWS WITH "IP 260" BARGES (Barge Size = 260 x 53 ft)		
1	355	53	95	1
2	630	53	110	3
3	905	53	125	4
4	1190	53	150	5

TABLE 2 (Continued)

No. Barges	Tow Length* Ft	Tow Width Ft	Pusher Length Ft	Lockage Type**
		TOWS WITH "J TANK" BARGES (Barge Size = 195 x 35 ft)		
1	265	35	70	1
2	460	35	70	2
3	675	35	90	3
4	890	35	110	4
5	1105	35	130	5
		TOWS WITH "S CHEM" BARGES (Barge Size = 200 x 52 ft)		
1	295	52	95	1
2	510	52	110	2
3	730	52	130	3
4	940	52	140	4
5	1140	52	140	5
6	1340	52	140	6
		TOWS WITH "IC 260" BARGES (Barge Size = 260 x 53 ft)		
1	355	53	95	1
2	630	53	110	3
3	905	53	125	4
4	1190	53	150	5
		TOWS WITH "IC 300" BARGES (Barge Size = 300 x 52 ft)		
1	390	52	90	2
2	710	52	110	3
3	1015	52	115	4
4	1340	52	140	5
		TOWS WITH "CEM 278" BARGES (Barge Size = 278 x 50 ft)		
1	370	50	92	2
2	646	50	92	3

TABLE 2. (Continued)

No. Barges	Tow Length * Ft	Tow Width Ft	Pusher Length Ft	Lockage Type**
	TOWS WITH "SGC 110" BARGES (Barge Size = 110 x 26 ft)			
1	170	26	60	55
2	170	52	60	55
3	280	52	60	1
4	280	52	60	1
5	390	52	60	44
6	390	52	60	2
7	530	52	90	2
8	530	52	90	2
9	640	52	90	2
10	640	52	90	2

*Tow length includes pusher length.

**Lockage types indicate number of cuts for standard lockages, except "55" which indicates multiple tow lockages are possible and "44" which is a single setover type lockage.

type lockages (e.g., triples, quadruples, etc.). In order to keep the Winfield Study costs down, the model was not modified to include separate processing time distributions for the larger tows using Winfield. The verification tests demonstrated that this did not significantly affect the results of the study, particularly since only the existing fleet characteristics were considered. When modeling the ready-to-serve locking procedure, all cuts of a tow are individually accounted for.

Detailed Barge and Commodity Data

21. The model requires additional statistics identifying the load characteristics of the 10 predominant barge types. These data were obtained by accumulating the number (count) and the tonnages of each commodity type moved by each of these barge types during the representative month of July 1975 (see Table 3). From the information in Table 3, the barge type used to transport each commodity group and the average load in tons involved were easily tabulated as shown in Table 4. Thus, the percent of each commodity type group carried by the various barge types was determined for use as input data in the simulation model. There was a variation in the distribution of barge types transporting some commodities during July as compared with the 4-month average. An adjustment was made to the July statistics as indicated in Table 4 to more closely represent the 4-month average. Commodity Group 6 was added to more accurately simulate the passage through the lock of the special cement barges using Winfield, particularly for projected conditions.

22. For purposes of model calibration, the directional movement of commodities during the month of July 1975 was determined. These data were obtained by tabulating the commodity type and tons by direction for each loaded tow. Tow data were then summarized as shown in Table 5.

TABLE 3

WINFIELD LOCKS TRAFFIC DATA SUMMARY - JULY 1975

Barge Type	No. Barges	PMS Commodity Code	Tons Cargo
R BULK	127	10	112,650
R BULK	24	51	19,050
R BULK	156	52	128,000
R BULK	30	60	22,000
R BULK	2	95	500
R BULK	1	99	100
	340		282,300
J BULK	92	10	123,900
J BULK	4	42	4,200
J BULK	1	45	400
J BULK	1	46	1,200
J BULK	12	52	14,400
J BULK	3	54	6,175
	113		150,275
IP 240	16	22	34,200
IP 260	20	22	56,245
IP 260	3	24	9,500
IP 260	4	25	3,890
	27		69,635

Barge Type	No. Barges	PMS Commodity Code	Tons Cargo
J TANK	2	21	2,400
J TANK	4	22	5,000
J TANK	1	26	1,200
J TANK	27	30	42,700
J TANK	3	31	3,400
J TANK	1	33	1,200
J TANK	1	34	1,200
J TANK	1	36	1,200
J TANK	8	38	10,400
	48		68,700
S CHEM	16	30	31,600
S CHEM	1	38	3,000
	17		34,600
IC 260	6	30	13,900
IC 260	5	31	14,000
IC 260	42	99	112,500
	53		140,400

Barge Type	No. Barges	PMS Commodity Code	Tons Cargo
IC 300	1	30	1,455
IC 300	14	35	31,400
IC 300	8	99	24,500
	23		57,355
CEM 278	7	61	17,600
SGC 110	70	52	23,250
SGC 110	5	99	1,300
	75		24,550
GRAND TOTAL	719		879,615

TABLE 4

WINFIELD STUDY COMMODITY GROUPS

Commodity Tonnages

Commodity	Barge Type	Tonnage
Group 1-Coal		
10	R BULK	112,650
10	J BULK	123,900
		236,550
Group 2-Chemicals		
30	J TANK	60,100
30	S CHEM	34,600
30	IC 260	27,900
30	IC 300	32,855
99	R BULK	100
99	IC 260	112,500
99	IC 300	24,500
99	SGC 110	1,300
		293,855
Group 3-Aggregates		
51	R BULK	19,050
52	R BULK	128,000
52	J BULK	14,400
52	SGC 110	23,250
60	R BULK	22,000
		206,700
Group 4-Petroleum		
20	J TANK	18,021*
20	IP 240	24,779
20	IP 260	69,635
		112,435
Group 5-Other		
40	J BULK	5,050*
54	J BULK	5,429*
62	--	0
95	R BULK	1,996*
		12,475
Group 6-Cement		
61	CEM 278	17,600

*Adjusted to represent 4-month average

Commodity Percentages by Barge Type

Commodity	Barge Type	Tonnage	%
Group 1			
10	R BULK	112,650	48
10	J BULK	123,900	52
		236,550	100
Group 2			
30	J TANK	60,100	20
30	S CHEM	34,600	12
30&99	IC 260	140,400	48
30&99	IC 300	57,355	20
99	R BULK	100	0
99	SGC 110	1,300	0
		293,855	100
Group 3			
51,52&60	R BULK	169,050	82
52	J BULK	14,400	7
52	SGC 110	23,250	11
		206,700	100
Group 4			
20	J TANK	18,021	16*
20	IP 240	24,779	22
20	IP 260	69,635	62
		112,435	100
Group 5			
40&54	J BULK	10,479	84*
62	--	0	0
95	R BULK	1,996	16*
		12,475	100
Group 6			
61	CEM 278	17,600	100

Average Load: Per Barge (Tons):

R BULK	830	IP 260	2860
J BULK	1340	S CHEM	2030
J TANK	1430	IC 260	2650
IP 240	2140	IC 300	2540
C		CEM 278	2510
		SGC 110	330

TABLE 5

Directional Movement of Commodities at Winfield During July 1975

Commodity	Tonnage (tons) Up	Down	Total
Group 1			
10	68,600	167,950	236,550
Group 2			
30	68,400	21,255	89,655
31	17,400	0	17,400
33	0	1,200	1,200
34	1,200	0	1,200
35	600	30,800	31,400
36	1,200	0	1,200
38	11,000	2,400	13,400
99	138,300	100	138,400
	238,100	55,755	293,855
Group 3			
51	19,050	0	19,050
52	165,650	0	165,650
60	22,000	0	22,000
	206,700	0	206,700
Group 4			
21	2,400	0	2,400
22	90,480	4,965	95,445
24	9,500	0	9,500
25	3,740	150	3,890
26	0	1,200	1,200
	106,120	6,315	112,435
Group 5			
42	4,200	0	4,200
45	400	0	400
46	1,200	0	1,200
54	4,200	1,975	6,175
62	0	0	0
95	500	0	500
	10,500	1,975	12,475
Group 6			
61	17,600	0	17,600

Tow Processing Times at the Current Winfield Locks

23. The analysis of the July 1975 tow processing times at Winfield is summarized in Table 6. The average lockage component times and frequencies of occurrence are given for each chamber on separate pages. An explanation of the lockage components listed in Table 6 follows:

a. Single lockages, Up and Down - Each tow requiring only one standard lockage (filling or emptying of the lock chamber once) with no reconfiguration of the tow was placed into this category and separated by the tow's travel direction (up or down).

b. Double, and Double Knockout, Setover and Jackknife Lockages, Up and Down - The vast majority of the lockage types falling into this category were double lockages, indicated in the PMS data base as a standard lockage requiring two cuts. There were a few double setover type lockages in July but no double knockouts or double jackknives.

c. Triple and Over Standard, Knockout, Setover, and Jackknife Lockages, Up and Down - No triple or over knockout, setover, or jackknife lockages were recorded by Winfield personnel during July. Tows requiring three, four, or five standard lockages were placed in this group and their chambering times computed.

d. Single Knockout, Setover, and Jackknife Lockages, Up and Down - These type lockages are also relatively rare at Winfield, but a few did occur so that a frequency distribution of chambering times could be developed.

e. Fly and Exchange Entries, Up and Down - The type of entry made by each tow is indicated in the PMS printout as a fly, exchange or turnback "approach." The fly and exchange type entries were grouped together since both are considered to be "long" entries, i.e., entries that involve transit of the approach channel.

f. Turnback Entries, Up and Down - Such entry types were grouped separately because of the shorter entry times normally involved. A turnback entry occurs when two vessels traveling in the same direction are locked sequentially, thus allowing the second tow to maneuver close to the lock entry gates while the first tow is being serviced. Thus, the second tow can normally position itself to make a turnback (or short) entry.

TABLE 6

FREQUENCY DISTRIBUTION OF LOCK COMPONENT TIMES
Winfield Lock - Chamber 1
(July 1975 Data)

COMPONENT DESCRIPTION	WTD AVE	TIME (MINUTES)												FREQUENCY OF OCCURRENCE (%)											
Single Lockages, Up	15	13	16											50	50										
Single Lockages, Down	12	10	13											25	75										
Double, Double Knockout, Setover, & Jackknife Lockages, Up	60	28	43	48	53	58	63	68	73	78	98			3	4	6	16	25	25	6	6	6	3		
Double, Double Knockout, Setover, & Jackknife Lockages, Down	49	33	38	43	48	53	58	83						6	22	17	6	33	11	5					
Triple & Over Standard, Knockout, Setover, & Jackknife Lockages, Up	136	80	90	100	110	120	130	140	150	170	200	220		7	5	7	22	9	9	7	10	7	12	5	
Triple & Over Standard, Knockout, Setover, & Jackknife Lockages, Down	132	80	90	100	110	120	130	140	160	190	210	220	240	11	12	9	8	8	17	6	8	15	2	2	2
Single Knockout, Setover, & Jackknife lockages, Up	26	20	25	30	40									29	43	14	14								
Single Knockout, Setover, & Jackknife Lockages, Down	26	20	25	30	40									29	43	14	14								
Fly & Exchange Entries, Up	22	3	8	13	18	23	28	33						8	2	14	14	28	10	24					
Fly & Exchange Entries, Down	15	3	8	13	18	23	28							9	13	33	21	13	11						
Turnback Entries, Up	8	2	5	13	18									50	9	8	33								
Turnback Entries, Down	6	2	8	18										64	18	18									
Exit, Up	4	3	4	6										33	33	34									
Exit, Down	2	1	2	3										25	25	50									
Turnbacks (or Swingarounds)	10	5	6	7	8	9	10	11	12	13	14	15	18	5	10	8	8	14	14	14	12	3	2	8	2
Open Pass Lockages, Short	--					NOT APPLICABLE																			
Open Pass Lockages, Long	--					NOT APPLICABLE																			
Break Times	--					NOT APPLICABLE																			
Remake Times	--					NOT APPLICABLE																			
Multiple Entry, Up	11	2	5	13	18	28	38							50	9	8	17	8	8						
Multiple Entry, Down	6	2	8	18	23									64	18	9	9								
Multiple Tow Lockages, Up	15	13	16											50	50										
Multiple Tow Lockages, Down	12	10	13											25	75										
Multiple Exits, Up	4	3	4	6										33	33	34									
Multiple Exits, Down	2	1	2	3										25	25	50									

TABLE 6 (Continued)

FREQUENCY DISTRIBUTION OF LOCK COMPONENT TIMES
Winfield Lock - Chamber 2
(July 1975 Data)

COMPONENT DESCRIPTION	WTD AVE	TIME (MINUTES)												FREQUENCY OF OCCURRENCE (%)											
Single Lockages, Up	14	10	13	16	19	31								50	19	6	6								
Single Lockages, Down	11	7	10	13	16									21	37	26	16								
Double, Double Knockout, Setover, & Jackknife Lockages, Up	63	48	53	58	63	68	73	83	88					9	17	22	22	9	9	9	3				
Double, Double Knockout, Setover, & Jackknife Lockages, Down	50	33	38	43	48	53	58	63	68	73				6	6	15	31	24	6	6	3	3			
Triple & Over Standard, Knockout, Setover, & Jackknife Lockages, Up	129	90	100	110	120	130	140	150	190	230	250			11	11	27	12	12	11	4	4	4	4		
Triple & Over Standard, Knockout, Setover, & Jackknife Lockages, Down	116	50	70	80	90	100	110	120	130	150	170	190		6	3	9	19	16	10	3	6	9	6	13	
Single Knockout, Setover, & Jackknife Lockages, Up	26	20	25	30	40									29	43	14	14								
Single Knockout, Setover, & Jackknife Lockages, Down	26	20	25	30	40									29	43	14	14								
Fly & Exchange Entries, Up	20	3	8	13	18	23	28	33						5	10	19	24	16	10	16					
Fly & Exchange Entries, Down	16	3	8	13	18	23	28							4	16	35	23	8	14						
Turnback Entries, Up	11	3	8	13	18									20	30	20	30								
Turnback Entries, Down	5	2												67	9	16	8								
Exit, Up	3	1	2	3	4	5	7							31	31	6	13	13	6						
Exit, Down	3	1	2	3	7	10								23	52	13	4	8							
Turnbacks (or Swingarounds)	10	5	6	7	8	9	10	11	12	13	14	15	18	12	8	10	6	11	7	10	17	4	4	4	7
Open Pass Lockages, Short	--	NOT APPLICABLE																							
Open Pass Lockages, Long	--	NOT APPLICABLE																							
Break Times	--	NOT APPLICABLE																							
Remake Times	--	NOT APPLICABLE																							
Multiple Entry, Up	15	3	8	13	18	28	43							20	30	20	10	10	10						
Multiple Entry, Down	5	2	5	8	11	17								67	9	16	8								
Multiple Tow Lockages, Up	14	10	13	16	19	31								50	19	19	6	6							
Multiple Tow Lockages, Down	11	7	10	13	16									21	37	26	16								
Multiple Exits, Up	4	2	5	8	11	17								67	9	16	8								
Multiple Exits, Down	3	1	2	3	4	5	7							31	31	6	13	13	6						

g. Exits, Up and Down - The exit times of single lockage tows only were compiled since the WATSIM defined exit times of tows requiring other lockage types could not be computed using the PMS data. The PMS exit times for these other lockage types include the time for reconfiguring the tow for transit in the river. This is considered to be a valid approach since almost all normal exit times are relatively short, regardless of tow size or horsepower.

h. Turnback - Times required to fill or to empty the lock and their frequencies of occurrence were recorded for each chamber.

i. Open-Pass Lockages, and Tow Break and Remake - These lockage components are not applicable at this time to the Winfield capacity study.

j. Multiple Entries, Up and Down - This involves the entry time required by two or more relatively small tows which are to be processed in a single lock operation. Due to the lack of data, turnback entry times were used to approximate multiple tow entry times. This approach should have no effect on the model results since multiple tow lockages occur very infrequently at Winfield.

k. Multiple Tow Lockages, Up and Down - Again, since no data were available, standard single lockage times and distributions were employed for modeling purposes in lieu of actual multiple tow lockage times.

l. Multiple Exits, Up and Down - Single lockage tow exit times were used for this data element also.

24. The lockage component times, computed using the PMS data were placed in groups according to their magnitude, the average of each time group computed, and a frequency distribution developed. From these data, the frequency of occurrence was computed on a percentage basis as shown in Table 6. The only deviation from the July 1975 prototype data concern a small number of recorded entry times that seemed to be excessively long. These long entry times were eliminated as unrepresentative samples and the occurrence frequencies of the longest entry times shown in Table 6 were increased. Subsequent tests of the effects of these modifications indicated that they had very little effect on the simulation run results. Concern was expressed to the Huntington District about these observed long times required for both fly and exchange approaches and turnback

approaches, some of which were nearly an hour in length. The Huntington District investigated this and verified that such long entries do occur. Reasons for such long approaches include:

a. The presence of one sharp bend in the downstream approach with a narrow channel, about 300 ft wide.

b. The extensive maneuvering required by a tow entering from the downstream approach.

c. The low horsepower of some of the towboats.

d. Under certain conditions of current and wind, maneuvering is excessively difficult.

e. Short river guard walls at the locks.

PART IV: TOWGEN/WATSIM MODEL CALIBRATION

General

25. This part of the report discusses the results of efforts to calibrate the simulation model to insure that it will reasonably reproduce selected historical prototype statistics. Tabular comparisons of the significant Winfield prototype data and the calibrated WATSIM output are shown in Tables 7, 8, and 9.

26. The statistical lockage data used for verification are summarized for both chambers as a single facility in Table 7 and for each chamber in Table 8. As shown in Table 7, prototype data used for verification covers the following three different periods:

a. July 1975.

b. Four-month average for May, July, Sep, and Dec 1975.

c. December 1975.

July 1975 data only were used for verification by chamber (Table 8).

27. The simulation runs were made for a typical 30-day month and then the results were adjusted for comparison with the two 31-day months (July and Dec). Cement was broken out as a separate commodity in the model so that the proper mix of the various types of barges could be more accurately reproduced by the model. As mentioned earlier entry times were revised slightly to eliminate the few entry times considered to be exceptionally high; however, this had essentially no effect on the simulation run results.

Adjustments to Input Data During Model Calibration Runs

28. Only a minimal number of simulation runs were required to calibrate the model. Before each separate run, the input data were adjusted as deemed necessary after careful study of the latest run. In general, the following significant adjustments to the input data

TABLE 7

WINFIELD LOCKS AND DAM SIMULATION MODEL VERIFICATION

Comparison of Total Results for Locks

Description	Verification Run 31 Days* July 75 Input	July 75	Difference %	4-Month Average**	Difference %	Verification Run 31 Days* Dec 75 Input#	Dec 75	Difference %
Total Tows	337	323	+4	328	+3	286	297	-4
Singles	14%	13%	+1	11%	+3	16	12%	+4
Doubles	33%	33%	0	35%	-2	29	35%	-6
Triples & Larger	51%	52%	-1	51%	0	53	51%	+2
Setovers	2%	2%	0	2%	0	2	2%	0
Loaded Barges	724	720		749		569	625	
Empty Barges	676 (48%)	684 (49%)	-1	646 (46%)	+2	498 (47%)	536 (46%)	+1
Utilization	41%	42.5%		--		35%	--	
Total Ktons	885	879	+1	911	-3	789	797	-1
Ave. Delay of Tows Delayed	58	43		--		78	--	
Ave. Delay of Tows Passing	17	18		--		18	--	
Ktons/tow	2.63	2.72		2.78		2.76	2.68	
Barges/tow	4.15	4.35		4.25		3.73	3.91	

*Adjusted from 30-day month values provided by simulation run.
**May, July, Sep, Dec 1975 (multiple tow lockages amounting to 1% of all lockages not included above).
#Dec 75 O-D matrix only; other input data based on July prototype data.

TABLE 8

WINFIELD LOCKS AND DAM SIMULATION MODEL VERIFICATION

Comparison of Results by Chamber

Description	Verification Run 31 Days* Jul 75 Input	Jul 75	Difference %
Chamber 1			
Total Tows	176	172	+2
Singles	11%	5%	+6
Doubles	21%	29%	-8
Triples & larger	67%	64%	+3
Setovers	2%	2%	0
Total Barges	721	798	-10
Utilization	49%	51%	
Chamber 2			
Total Tows	161	151	+7
Singles	19%	23%	-4
Doubles	46%	37%	+9
Triples & larger	33%	38%	-5
Setovers	2%	2%	0
Total Barges	679	606	+12
Utilization	33%	34%	

*Adjusted from 30-day month values provided by simulation run.

TABLE 9

WINFIELD LOCKS AND DAM SIMULATION MODEL VERIFICATION

Comparisons of Results Using 1975 Total Annual Tonnages

Description	Verification Run 31 Days* Total 1975 Input#	4-Month Average**	Difference %
Total Tows	336	328	+2
Singles	8%	11%	-3
Doubles	34%	35%	-1
Triples & larger	56%	51%	+5
Setovers	2%	2%	0
Loaded Barges	742	749	
Empty Barges	607 (45%)	646 (46%)	-1
Utilization	42.5%	--	
Total Ktons	912	911	0
Ave. Delay of Tows Delayed	59	--	
Ave. Delay of Tows Passing	18	--	
Ktons/tow	2.71	2.78	
Barges/tow	4.02	4.25	

*Adjusted from 30-day month values provided by simulation model.

**May, July, Sep, Dec 1975 (multiple lockages amounting to 1% of all lockages included above).

#Total 1975 tonnages by commodity were based on the lockmaster's records. Directional movements were based on 1974 percentages. Cement was broken out of the commodity grouping "Other" in the same proportion as estimated for 1980 (Reference: ORJED-PE letter dated 12 May 1976, subject: Capacity Studies of Winfield Lock and Dam, Kanawha River). Annual tonnages were reduced internally by the model through input data (tonnage divisions) to represent equally distributed monthly averages.

were made to calibrate the model:

a. The horsepower vs number of barges per tow frequency distribution (often referred to as tow codes) was revised slightly to permit the model to more closely reproduce the actual mix of the several different lockage types, i.e., singles, doubles, etc. This change was based on the observation that there was a large number of tows with mixed barge types that required double lockages. As these tows are not modeled directly, the size distributions of the regular and jumbo hopper barges were adjusted to represent these tows in the vessel mix. This brought the ratio of lockage types into close agreement with observations.

b. Dedicated equipment percentages for several of the barge types were adjusted in order to reproduce the correct ratio of empty-to-loaded barges passing the locks. There appears to be a large number of independent operators, and small towing companies operating on the Kanawha. Therefore, even though commodities using the same or similar barge equipment move in both directions, most of these movements involve empty backhauls. Interlining of equipment does not appear to occur frequently.

c. Chamber penalty times for selected lockage types were varied in several runs so that the use of the two chambers by various size tows could be more closely represented. This is influenced by the heavy use of Chamber 2 for recreational craft lockages and by the program logic used in selecting chambers. WATSIM assumes the second chamber to be less used than the first chamber because usually that chamber is smaller. At Winfield, both chambers are the same size.

Summary of Calibration Results

29. A review of Tables 7, 8, and 9 indicates that the final calibration run results and corresponding prototype data compare exceptionally well with one another in almost every case. A primary measure of good modeling results is the reproduction of the number of observed tows, tonnage, ratios of lockage types, and ratio of empty to loaded barges. As indicated by Table 7, the total number of tows passing through the lock during the sampling period is reproduced within 4 percent by the model. The tonnage passing the lock is reproduced within 1 percent using

calibration input data (lockage component times, flotilla makeup, tonnages, etc.) and the July tonnage O-D matrix, and comparing the results with the actual July prototype data; within 3 percent using calibration input data and July tonnages and comparing the results with the 4-month average; and within 1 percent using the actual December tonnage O-D matrix together with calibration input data and comparing the results with December prototype data. The ratio of the four lockage types analyzed and the ratios of empty to loaded barges (percent empties) also compare favorably in each of the three cases shown on Table 7.

30. Table 8 shows the comparison of simulation model results and July prototype data by chamber. The model automatically assigns each approaching tow to one of the two chambers by considering the expected time for completion of lockage, accounting for vessels in queue and chamber penalty times, if any, as primary criteria for chamber selection. Since the model internally controls the assignment of tows to the chambers, the differences between the model's output and corresponding July data are not considered to be too great especially considering that Chamber 2 is used heavily for locking recreational craft which are not reproduced in WATSIM. It should be observed that the model correctly simulates the observed tendency for large tows to favor the use of Chamber 1. All comparative data are within 10 percent of one another except the total barges processed by Chamber 2, which deviates by only 12 percent from the actual count.

Seasonality of Commodity Movements

31. Since historical monthly tonnage data were available for 1970 through 1975, the effect of seasonal movement variations on lock utilization was investigated. A review and analysis of these monthly tonnage levels revealed that slight seasonal variations exist for only one commodity group: stone, sand, and gravel. However, peak movements for all commodities appeared during all months over the 6-year period of

record irrespective of the season. Using the 4-month averages for verification purposes, a test run of the model was made using 1975 total annual tonnages in the O-D matrix, dividing the movements equally over the 12-month period for each of the six commodity groups. This, in essence, assumes no seasonal variation since total annual tonnages for each commodity are divided by 12.0 to get a monthly average for the year. A comparison of model results and the 4-month averages is shown in Table 9. The close reproduction of prototype data using 1975 total tonnages as input data further strengthens the accuracy and validity of the WATSIM model. Due to the seasonality of the aggregate movements, greater delays would probably be experienced at Winfield at some times during each year than at other times; however, the only apparent effect is due to the increased tonnage passing during that period, not the mix of vessels. This can easily be accounted for in determining annual delay values for projected periods, as will be explained in Part V.

PART V: CAPACITY DETERMINATIONS OF THE EXISTING WINFIELD LOCKS

General Method of Determining Capacity

32. Two primary approaches were used to analyze the capacity of existing lock facilities at Winfield: increases in delay times and lock utilization as functions of increased commodity tonnages. Both methods should yield similar results since the delays increase rapidly as lock utilization approaches 100 percent. Delay times reflect the economic costs to shippers and are indicative of both economic and physical capacity constraints. Lock utilization values are more indicative of the approach to physical capacity. Such studies give a good indication of the current lock's capability to handle the projected traffic levels. For each alternative lock operating policy, the analysis involved plotting the experimentally determined values, determining the range of experimental sample values, fitting functions, and plotting curves to these data points using the least squares method. These plots are included in Part VI of this report. Further statements of general applicability to the capacity studies of Winfield are contained in the remaining sections of Part V.

Lock Operating Policies Studied

33. The following four operating policies were analyzed separately to determine the positive impact of these potentially less expensive alternative interim solutions:

a. First In, First Out (FIFO), Unrestricted - This simply means that the tows are serviced in the order of their arrival and that no restriction is placed on their barge configuration (tow makeup) or size as they approach the lock, i.e., no remake or reconfiguration of the barges is required until after the lockage process begins.

b. FIFO, Unrestricted with a 10 Percent Reduction in Lockage Component Times - All lockage component times were arbitrarily reduced by 10 percent to determine the effects of improving the overall efficiency of locking operations regardless of the methods employed.

c. FIFO Ready-to-Serve - This operating policy prohibits the break and remake of tows within or in the vicinity of a lock chamber. Each separate cut of a large tow is assumed to lock immediately following one another and is considered to be independently powered. This operating policy would require several switchboats at the lock at all times to assist in the locking operations and, therefore, may not be practical. Further discussion of the Ready-to-Serve policy is included in Reference 2.

d. 3 Up-3 Down - Three upbound tows are locked consecutively followed by three downbound tows, or vise versa. If the queue in the pool from which tows are being locked empties prior to reaching the maximum of three vessels, tows from the other pool are then selected. For this policy, it is assumed that the last two tows in sequence will approach the lock and, therefore, their entry will be of the turnback (or short) entry type.

Reduction and Analysis of WATSIM Output

34. As discussed in Appendix B, the WATSIM program prints for each 3-day sample period the cumulative delays, commodity tonnage, and tows processed from the beginning of the simulation to that period. A total of 10 sample interval printouts are thus obtained from a single WATSIM run. The sample intervals chosen for analysis of the existing Winfield locks were five 3-day periods. The delays, tonnages, etc., were then increased by a magnitude of 10 to obtain monthly values (assuming a 30-day month). Appendix B discusses the rationale for choosing the 3-day intervals and compares a number of other possible intervals that could have been selected. Appendix B also includes a table of the five sample time intervals used in this study.

35. The data taken directly from Table 13 of the WATSIM printouts are tabulated as shown for each alternative operating policy in Appendix C. For each year included in the study, the number of tows, monthly delay, and monthly tonnage were computed for the sample intervals. Monthly delays and tonnages were simply multiplied by 12 to obtain the annual delays and tonnages shown in Appendix C. In addition, the percent

utilization during each sample interval was recorded. The monthly delays and tonnages were plotted initially and then consideration of the effects of monthly variations in the commodity movements were accounted for by plotting annual delay and tonnage curves, as described in Paragraph 37. The unadjusted annual delays and tonnages shown in Appendix C were used to generate the tonnage vs utilization and delay vs utilization plots.

Projected Tonnage Levels

36. The 1975 and future year tonnage levels used in the simulation runs are shown in Table 10. The "Notes" below the table explain the source of these tonnages. Since projected tonnages for 1980 and 1990 only were available, a simple scheme for increasing tonnages in steps was used in order to simulate infinite queuing conditions at the existing locks. Tonnages for each commodity were increased by reducing the "divisors" in the TOWGEN deck before each run. This procedure is explained in more detail in Appendix D. The years beyond 1990 (1993, 1998, etc.) in Table 10 relate to the tonnages obtained by using the divisors 11.0, 10.0, etc., and the trend of total tonnage increase between the years 1980 and 1990. This in effect assumed that all commodities would grow at the same rate and the proportionate distribution of the commodity tonnages would remain constant. The relationship between 1993 and the divisor of 11.0 is shown in Table D1. A trend projection method could also have been used with slightly more effort involved in changing the cards before each TOWGEN run. However, it was felt that in view of the variations in the sample delays and the high projected utilization of the lock in 1990, very little difference would be recognized in the WATSIM output (tonnages, delays, etc.), regardless of which projection method was used for years in the distant future. In addition, Huntington District had expressed concern about the validity of projected tonnages beyond 1990 and considered that

TABLE 10

PROJECTED ANNUAL TONNAGE LEVELS FOR WINFIELD LOCKS AND DAM
(K TONS)

Commodity	1975	1980	1985	1990	Year 1993 11.0*	1998 10.0*	2002 9.0*	2009 8.0*	2017 7.0*
Coal	3,783	7,252	8,439	9,626	10,501	11,551	12,839	14,439	16,502
Up	265	609	949	1,288					
Down	3,518	6,643	7,490	8,338					
Chemicals	3,392	6,732	8,455	10,177	11,102	12,212	13,569	15,266	17,446
Up	3,087	6,032	7,620	9,208					
Down	305	700	835	969					
Aggregates	1,655	1,952	1,927	1,903	2,075	2,283	2,537	2,855	3,262
Up	1,638	1,946	1,922	1,899					
Down	17	6	5	4					
Petroleum	1,111	1,166	1,371	1,576	1,719	1,891	2,101	2,364	2,702
Up	1,078	1,143	1,347	1,551					
Down	33	23	24	25					
Other	639	691	865	1,038	1,132	1,245	1,384	1,557	1,779
Up	537	599	751	903					
Down	102	92	114	135					
Cement	160	173	171	168	183	202	224	252	288
Up	160	173	171	168					
Down	0	0	0	0					
All Com.	10,740	17,966	21,228	24,488	26,712	29,384	32,708	36,733	41,979
Up	6,765	10,502	12,760	15,017					
Down	3,975	7,464	8,468	9,471					

*Divisor

Notes: 1975 tonnages are based on lockmasters' records; 1980 and 1990 projections were determined by the Huntington District (ORHED-PE). 1985 tonnages are linear in interpolation of the growth rate between 1980 and 1990; 1993 and beyond tonnages were artificially produced by using TOWGEN "Tonnage Divisors" of 11.0, 10.0, 9.0, 8.0 and 7.0. The years 1993, 1998, 2002, 2009, and 2017, respectively, were assigned to these tonnage levels based on linear extrapolations of the projected 1980 and 1990 tonnages.

resource studies should be initiated prior to accepting any projected tonnage levels for time periods beyond that year. Since these tonnage levels were being used only for establishing the locks' capacity, the more straightforward approach was selected. A comparison of the tonnages obtained from both methods is given in Appendix D also.

Procedures Used to Develop the Lock Capacity Curves

37. Based on output from the simulation model, a monthly delay versus monthly tonnage plot was made for each of the four alternative operating policies tested (see Part VI). These plots show the rate that monthly delays are expected to increase as tonnages moving through Winfield grow in future years. The extremely high delays are indicated at the top of each figure, where appropriate, to indicate the magnitude of the values that could not be plotted. From these monthly plots and the historical data on monthly variations in commodity movements, a plot of adjusted annual delays versus annual tonnages was developed. This plot is shown later in the report but the method used to produce it will be explained here, since all four alternative lock operating policies are involved. To a degree, the adjusted annual plots developed in this manner take into consideration the effects of the slight seasonal variations in the traffic passing through Winfield.

38. The monthly movement of commodities for a 6-year period (1970-1975) was available from the lockmaster's records. Table 11 shows these monthly tonnage levels in terms of average percentages of the total annual movements during this period. Actual 1975 monthly tonnages are also shown together with projected monthly levels for future years, based on the historical monthly averages. With these tonnage values, the delays shown for each alternative lock operating policy were obtained from the appropriate monthly delay versus monthly tonnage plot. The total annual delays and tonnages shown in Table 11 were then plotted for each operating policy as four separate curves in

TABLE 11

WINFIELD L&D CAPACITY STUDY
Estimated Monthly Tonnages and Delays
Existing 360'x56' for Dual Chamber Locks

Month	Percent[1]	Actual 1975 Tons (000)	Projected Tonnages (000) 1980	1985	1990	1993	1998	2002	2009	2017
January	7.6	949	1,366	1,613	1,861	2,030	2,233	2,486	2,792	3,191
February	7.3	768	1,312	1,550	1,787	1,950	2,145	2,388	2,682	3,065
March	8.3	821	1,491	1,762	2,033	2,217	2,439	2,715	3,048	3,484
April	8.4	957	1,509	1,783	2,057	2,244	2,468	2,747	3,086	3,526
May	9.2	991	1,653	1,953	2,253	2,458	2,703	3,009	3,379	3,862
June	8.8	921	1,581	1,868	2,155	2,350	2,586	2,878	3,233	3,694
July	8.2	862	1,473	1,741	2,008	2,190	2,409	2,682	3,012	3,442
August	9.0	823	1,617	1,910	2,204	2,404	2,645	2,944	3,306	3,778
September	8.6	946	1,545	1,826	2,106	2,297	2,527	2,813	3,159	3,610
October	8.9	964	1,599	1,889	2,179	2,377	2,615	2,911	3,269	3,736
November	8.0	921	1,437	1,698	1,959	2,137	2,351	2,617	2,939	3,358
December	7.7	818	1,383	1,635	1,886	2,058	2,263	2,518	2,828	3,233
TOTALS	100.0	10,741	17,966[2]	21,228	24,488[2]	26,712[3]	29,384[3]	32,708[3]	36,733[3]	41,979[3]

Month	FIFO, Unrestricted Delays (hrs) July 1975 Lockage Component Times 1975	1980	1990	1993	1998
January	145	440	1,230	1,820	Infinite Queuing Occurs at 16,970 Minutes
February	82	380	1,060	1,510	
March	100	580	1,820	>3,000	
April	150	590	1,940	>3,000	
May	175	800	>3,000	>3,000	
June	137	700	>3,000	>3,000	
July	110	550	1,740	>3,000	
August	102	750	>3,000	>3,000	
September	143	645	2,320	>3,000	
October	155	720	>3,000	>3,000	
November	137	515	1,540	2,680	
December	98	455	1,310	2,000	
TOTALS	1,534	7,125	>24,960	>32,010	

Month	FIFO, Unrestricted Delays (hrs) 10% Reduction in Jul 75 Lockage Component Times 1975	1980	1990	1993	1998	2002
January	80	330	1,010	1,430	2,480	Infinite Queuing Occurs at 29,875 Minutes
February	20	280	880	1,200	1,900	
March	40	460	1,430	2,400	>3,000	
April	82	480	1,500	2,600	>3,000	
May	100	650	2,730	>3,000	>3,000	
June	70	565	1,950	>3,000	>3,000	
July	50	445	1,360	2,120	>3,000	
August	40	615	2,240	>3,000	>3,000	
September	80	520	2,690	>3,000	>3,000	
October	84	590	2,100	>3,000	>3,000	
November	70	400	1,230	1,820	>3,000	
December	38	350	1,060	1,520	>3,000	
TOTALS	754	5,685	20,180	>28,090	>34,380	

Month	FIFO, Ready-To-Serve Delays (hrs) July 1975 Lockage Component Times 1975	1980	1990	1993	1998	2002	2009	2017
January	25	55	245	355	510	765	1,240	Infinite Queuing Occurs at 17,593 Minutes
February	20	43	205	300	440	660	1,020	
March	21	82	360	515	710	1,080	>3,000	
April	25	90	375	520	740	1,150	>3,000	
May	26	140	525	735	1,060	2,080	>3,000	
June	24	115	445	620	880	1,460	>3,000	
July	22	80	340	480	670	1,020	3,000	
August	21	125	485	675	960	1,660	>3,000	
September	25	100	405	575	810	1,280	>3,000	
October	25	120	475	645	920	1,560	>3,000	
November	24	65	305	430	620	920	1,700	
December	21	58	260	375	530	800	1,320	
TOTALS	279	1,073	4,425	6,225	8,850	14,435	>29,280	

Month	3U3D Delays (hrs) July 1975 Times 1975	1980	1985	1990
January	225	630	1,008	1,800
February	130	550	915	1,480
March	160	800	1,400	>3,000
April	230	840	1,460	>3,000
May	250	1,100	2,260	>3,000
June	210	970	1,600	>3,000
July	180	770	1,340	>3,000
August	161	1,010	2,040	>3,000
September	227	910	1,640	>3,000
October	240	1,000	1,900	>3,000
November	210	740	1,220	2,500
December	158	640	1,060	1,900
TOTALS	2,381	9,960	18,043	>31,680

[1] Average monthly percentages based on 1970-1975 commodity movements.

[2] Provided by Huntington District (ORHED-PE).

[3] Estimated by using 11.0, 10.0, 9.0, 8.0, and 7.0, respectively, as commodity tonnage divisors in TOWGEN for the years 1993, 1998, 2002, 2009, and 2017. The "divisor" method was used as a expeditious means of increasing tonnage until infinite queuing occurred at the lock facility for a specified operating condition (see Appendix D).

a single figure. For the exceptionally high tonnage levels that occurred after the monthly delay versus tonnage curves became vertical, the value ">3000" was used in order to obtain the totals in Table 11. Some of the high projected tonnages would undoubtedly have resulted in total delays much longer than 3000 hours; however, the exact figures for these delays could not be obtained from the curves. Therefore, these adjusted annual delay values are only illustrative of the delays that might be incurred. In reality, the full tonnage levels for those months could not have been serviced and the traffic would have been diverted or would have been delayed until a month with less tonnage.

39. As indicated in Table 11, tonnages were increased until "infinite queuing" occurred in the simulation model. This means that the traffic waiting to be serviced reached the preset limit of 30 tows. This value, though set arbitrarily, was chosen for two reasons. First, 30 tows waiting to be serviced on each side of the lock is considered an "impossible" situation from a practical standpoint, especially since the average interarrival time (time between tows arriving at the locks) at that traffic level is much less than the average service time. Secondly, as in the prototype, the queues are not static, but build and diminish. With a more reasonable preset queue limit (say 15 tows), a slight increase in the number of tows in queue might cause premature termination of a simulation run, i.e., infinite queuing would occur due to an unusual series of tow arrivals. To avoid such occurrences and to allow very high lock utilization values and tow delays, a large number, e.g., 30 for these runs, was selected.

Interpretation of the Capacity Curves

40. The delay versus tonnage curves become asymtotic as tonnage levels increase. That is, at some point on the delay versus tonnage curve, a slight increase in tonnage will cause an extremely large increase

in total delay. When this occurs, an unstable condition in the relationship between delay and tonnage develops, producing a band of uncertainty in the capacity. A least squares regression of an exponential function was attempted for all test cases; however, the exponential function diverges in the area of instability due to the fact that it is an ever increasing function and has no asymtotic value.

41. The region where the delay versus tonnage level approaches an asymtotic value of tonnage defines the physical limitation of tonnage or capacity that can be serviced under the given operating conditions (service times, lock operating policy, fleet characteristics and commodity mix at given tonnage levels). Practical tonnage capacity levels would fall below this region due primarily to three reasons:

<u>a</u>. At such high lock utilization levels, the total delay of tows is very sensitive to the specific tow arrival pattern.

<u>b</u>. Small changes in particular queuing characteristics can cause dramatic increases in the delay costs incurred by the towing industry.

<u>c</u>. No allowance is made in the simulation procedure for maintenance and accident downtime nor for utilization of the locks for recreational craft and work boats.

42. A study of lock utilization as a function of tonnage and/or delay is another way to determine the capacity of a lock. The tonnage versus utilization is linear in most cases and once a specific value of utilization is chosen to represent a capacity level of usage, a specific level of tonnage associated with that utilization can readily be obtained for use in an economic evaluation of both structural and nonstructural alternative lock improvements. The delay versus utilization curve is provided so that a corresponding total delay time to be expected for a particular utilization can also be determined.

43. With the tonnage versus utilization and delay versus utilization plots, some of the other variables of lock operation can be considered by adjusting utilization and obtaining a revised capacity level. This becomes necessary because the simulation model does not account for all

factors involved in the capacity of a lockage facility. For example, the simulation model used for this study considers only the tows with one or more barges. It has no direct means of introducing work boats, towboats without barges, pleasure craft or other relatively small, but often numerous, boats into the simulation process. The utilization curves provide a means of subtracting the percentage of lock utilization attributed to these other users. Another factor, downtime due to mechanical failures, maintenance, or accidents can also be easily compensated for by using these types of capacity definitions.

PART VI: WINFIELD CAPACITY LEVELS FOR FOUR ALTERNATIVE OPERATING POLICIES

General

44. Figure 3 lists the simulation run sets made for each of the four alternative operating policies tested. Numerous additional runs were initially planned for the study but had to be suspended to concentrate efforts on the Gallipolis study. Only a "Most Likely" tonnage projection set was used in the capacity tests even though plans also called for considering an alternate (either high or low) projection set. As shown in Figure 3, only the existing Winfield lockage facilities were simulated. The other lock system alternatives to be studied at a later date include:

- a. Dual 800- x 110-ft chambers at the current site.
- b. Dual 800- x 110-ft chambers at a selected site upstream from the current site.
- c. Dual 800- x 110-ft chambers located in a channel cut through a bend near the present dam.
- d. Either dual 1200- x 110-ft chambers or dual 600- x 110-ft chambers, depending upon the results of previous simulation runs (site to be selected).
- e. A single chamber lock either 1200- x 110-ft or 600- x 110-ft, whichever is selected, so that phased construction of the dual chambers can be considered.

Three fleet characteristic sets were planned since simulation results are sensitive to the types and sizes of the flotillas using the locks. This effect is primarily caused by the type of lockages (singles, doubles, setovers, etc.) required to process the various sized flotillas. The three proposed fleet characteristics included the currently observed tow makeups passing the Winfield Locks, the currently observed tow makeups passing the Gallipolis Locks on the Ohio River, and a set of fleet characteristics that make optimum use of the proposed lock sizes. The use of the Ohio River fleet characteristics would allow evaluation of the impact resulting from a shift of tow makeups toward the sizes operating on the Ohio. The traffic on the Kanawha River will most likely

Run Number	Description*
1M01WFU75	FIFO-Unrestricted (FU), Year 1975
2M01WFU80	FU, Year 1980
3M01WFU90	FU, Year 1990
4M01WFU93	FU, Year 1993 (Tonnage divisor = 11.0 ea. commodity)
5M01WFU98	FU, Year 1998 (Tonnage divisor = 10.0 ea. commodity)
6M01WFU75	FU, Year 1975, 10% reduction in all lockage times**
7M01WFU80	FU, Year 1980, 10% reduction in all lockage times**
8M01WFU90	FU, Year 1990, 10% reduction in all lockage times**
9M01WFU93	FU, Year 1993 (Tonnage divisor = 11.0 ea. commodity), 10% reduction in all lockage times**
10M01WFU98	FU, Year 1998 (Tonnage divisor = 10.0 ea. commodity), 10% reduction in all lockage times**
11M01WFU02	FU, Year 2002 (Tonnage divisor = 9.0 ea. commodity) 10% reduction in all lockage times**
12M01WFR75	First In First Out-Ready to Serve (FR), Year 1975
13M01WFR80	FR, Year 1980
14M01WFR90	FR, Year 1990

* All runs were made using a most likely tonnage projection set, current Winfield L&D fleet characteristics, and the existing Winfield lockage facilities.

** Includes all components of the lockage procedure, i.e., entry, chambering, and exit.

Figure 3. Simulation model runs for the Winfield L&D Capacity Study (Single Lock Configuration)

Run Number	Description*
15M01WFR93	FR, Year 1993 (Tonnage divisor = 11.0 ea. commodity)
16M01WFR98	FR, Year 1998 (Tonnage divisor = 10.0 ea. commodity)
17M01WFR02	FR, Year 2002 (Tonnage divisor = 9.0 ea. commodity)
18M01WFR09	FR, Year 2009 (Tonnage divisor = 8.0 ea. commodity)
19M01WFR17	FR, Year 2017 (Tonnage divisor = 7.0 ea. commodity)
20M01W3U75	3 Up-3 Down, Unrestricted (3U), Year 1975
21M01W3U80	3U, Year 1980
22M01W3U90	3U, Year 1990
23M01W3U85	3U, Year 1985

Figure 3 (Cont.)

be tending towards these characteristics. The optimum sized tow set would demonstrate what efficiencies could be obtained if the towing industry could make up its tows in that manner. To date simulation runs include only the current Kanawha River fleet characteristics.

FIFO - Unrestricted Operating Policy

45. The capacity curves for this operating policy are shown in Figures 4, 5, and 6. Figure 4 defines the minimum and maximum limits of the region of instability of the locks to be 1.88 and 2.39 million tons per month, respectively. The legend in Figure 4 includes utilization increases with increasing traffic.

FIFO - Unrestricted with a 10 Percent Reduction in Lockage Component Times

46. The lockage component time distributions obtained from an analysis of the July 1975 prototype data and used in the FIFO - Unrestricted runs discussed above were reduced by 10 percent to model the effect of more efficient locking operations, by whatever means this might be accomplished. This resulted in a capacity increase of less than 10 percent in both the minimum and maximum limits of the region of instability 2.00 and 2.55 million tons per month, respectively, as shown in Figure 7. Figures 8 and 9 are the accompanying tonnage versus utilization and delay versus utilization plots for use in determining tonnages and delays associated with selected levels of lock utilization.

FIFO - Ready-to-Serve Operating Policy

47. As expected, dramatic increases in the capacity of the locks could be attained if the FIFO - Ready-to-Serve operating policy is practical. Figures 10, 11, and 12 graphically summarize the results of

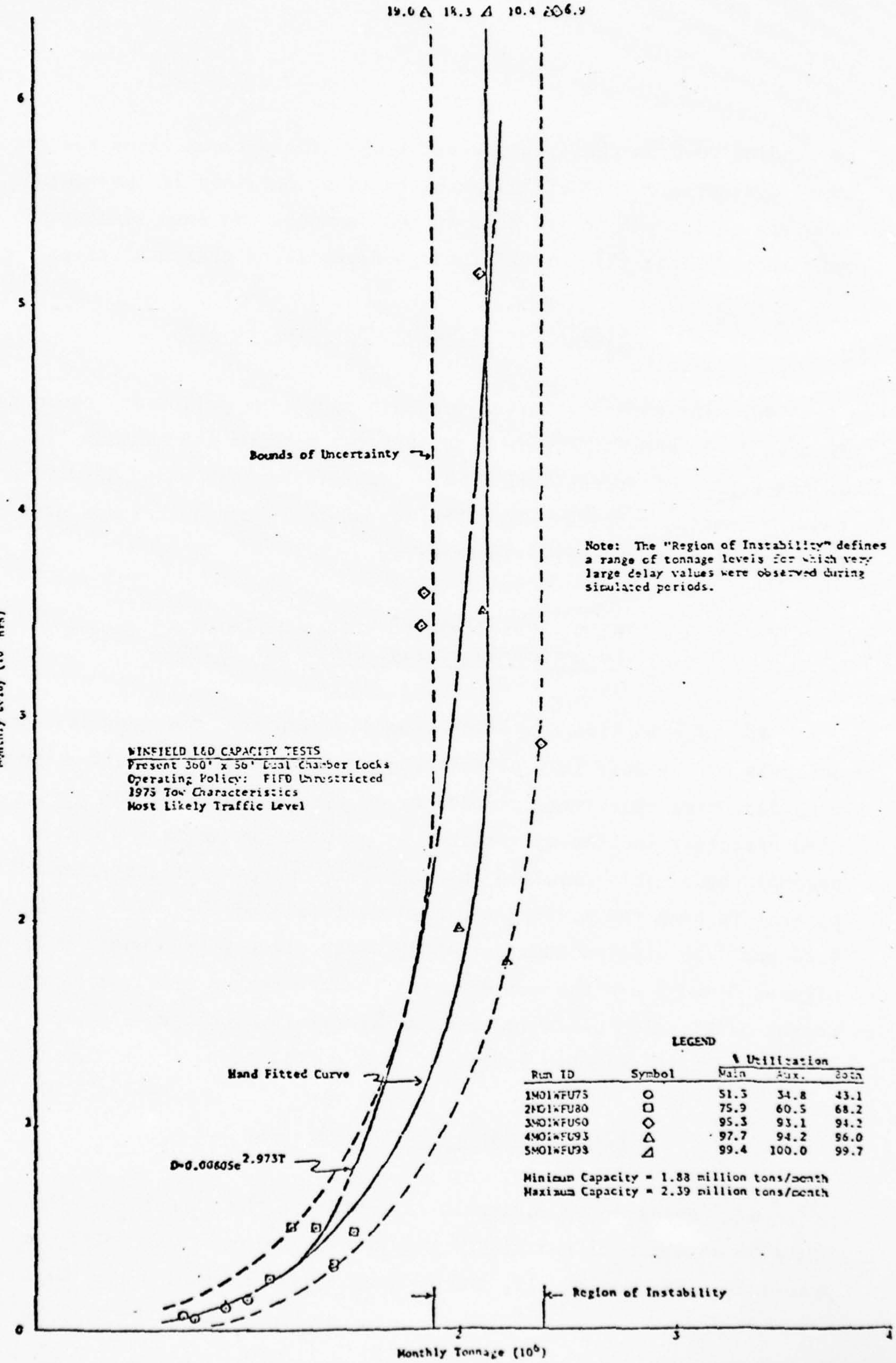

Figure 4. Monthly Delay vs Monthly Tonnage for the FIFO-Unrestricted Operating Policy

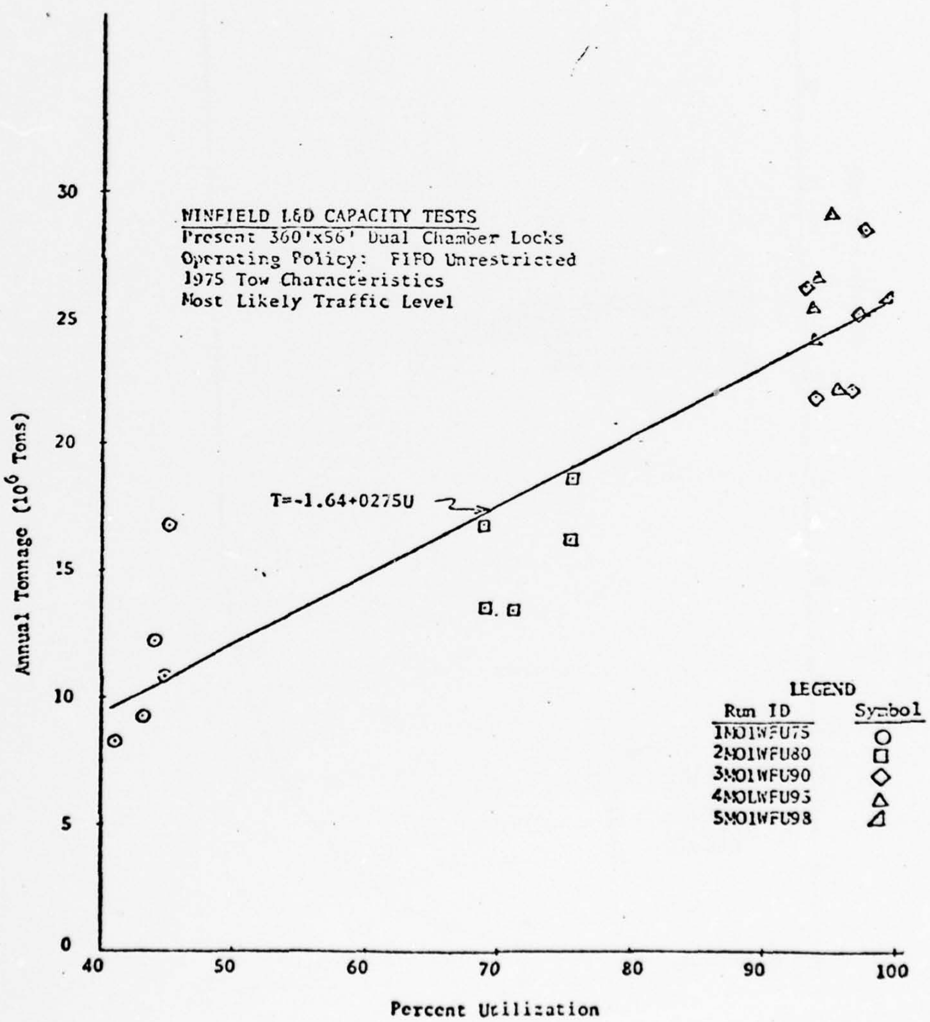

Figure 5. Annual Tonnage vs Utilization for the FIFO-Unrestricted Operating Policy

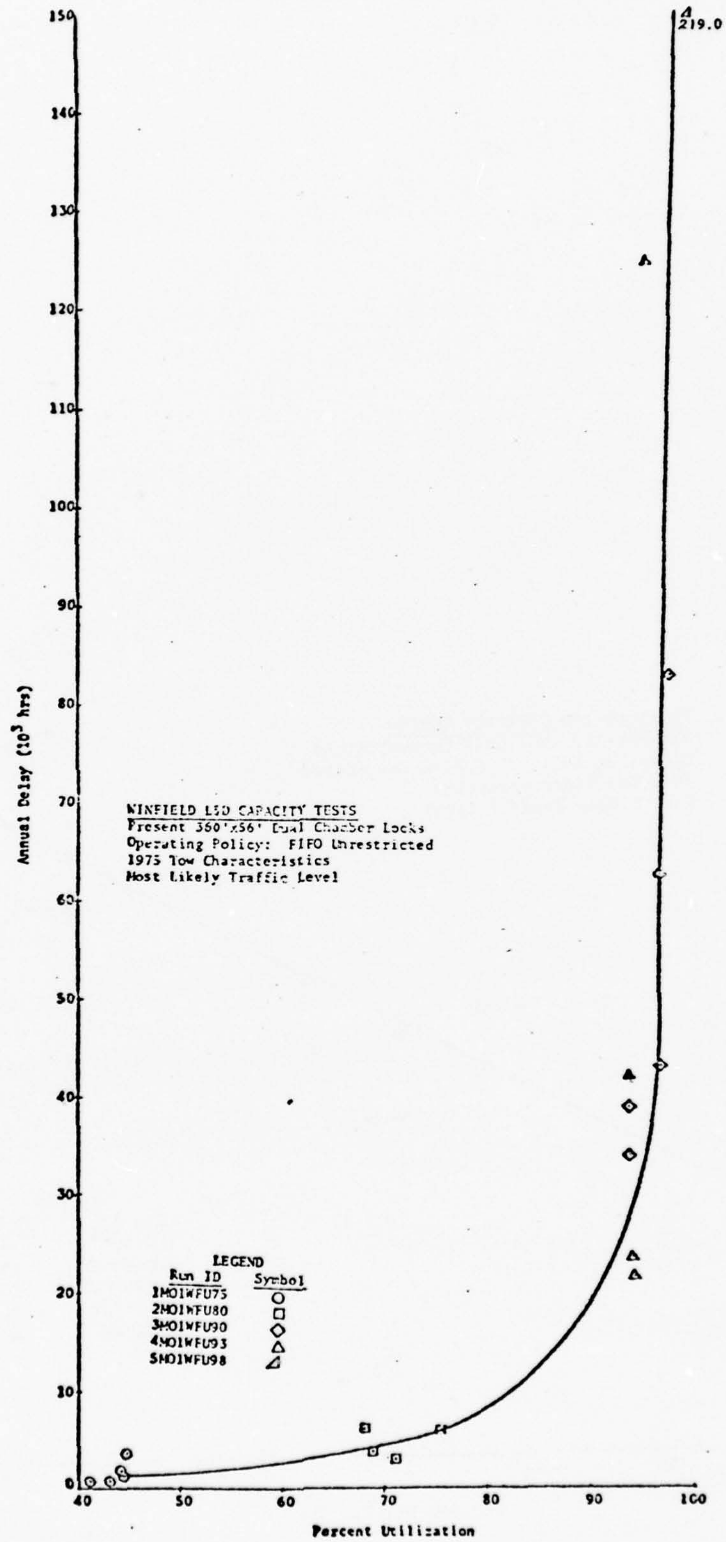

Figure 6. Annual Delay vs Utilization for the FIFO-Unrestricted Operating Policy

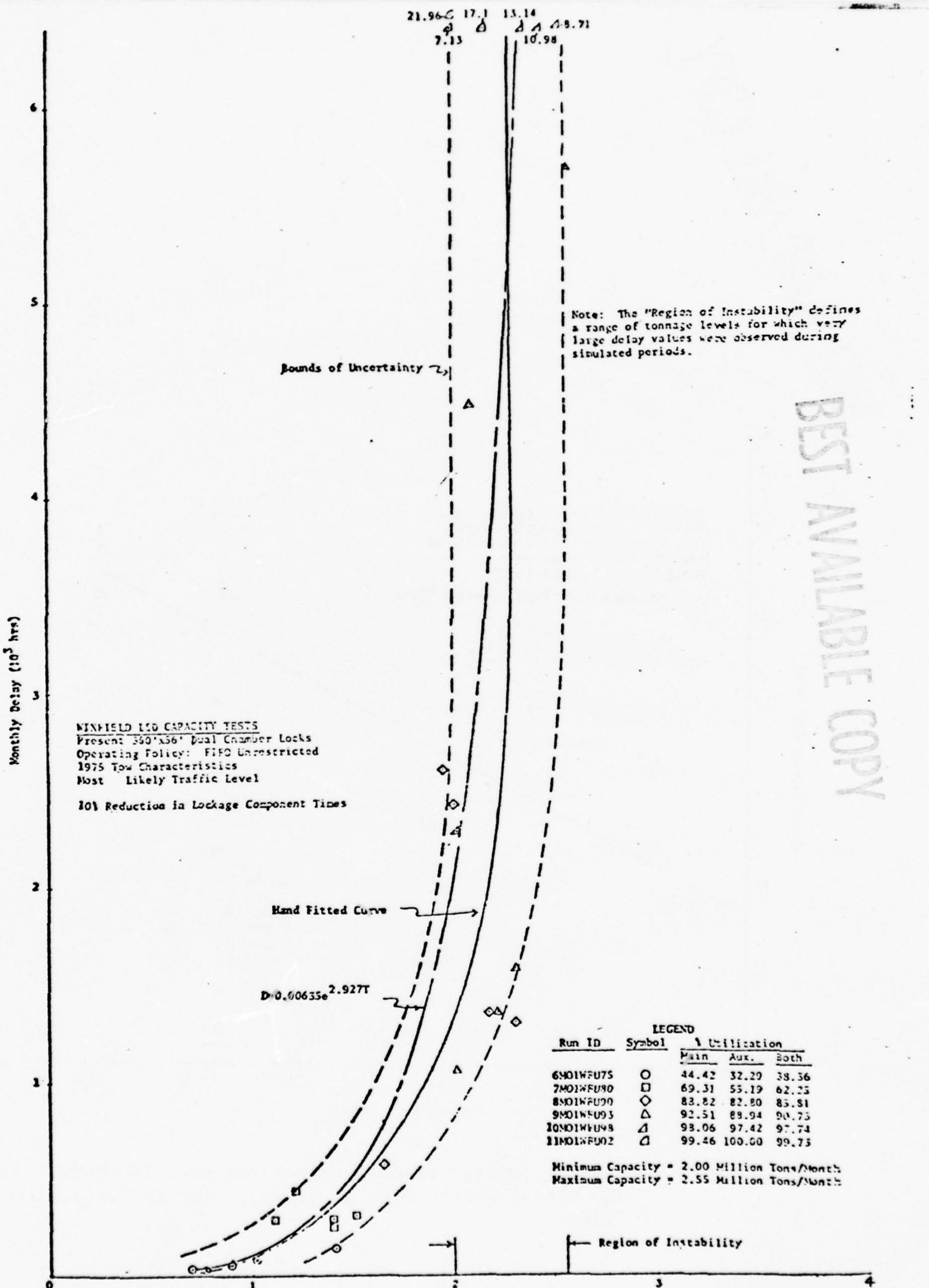

Figure 7. Monthly Delay vs Monthly Tonnage for the FIFO-Unrestricted Operating Policy with a 10% Reduction in Lockage Component Times

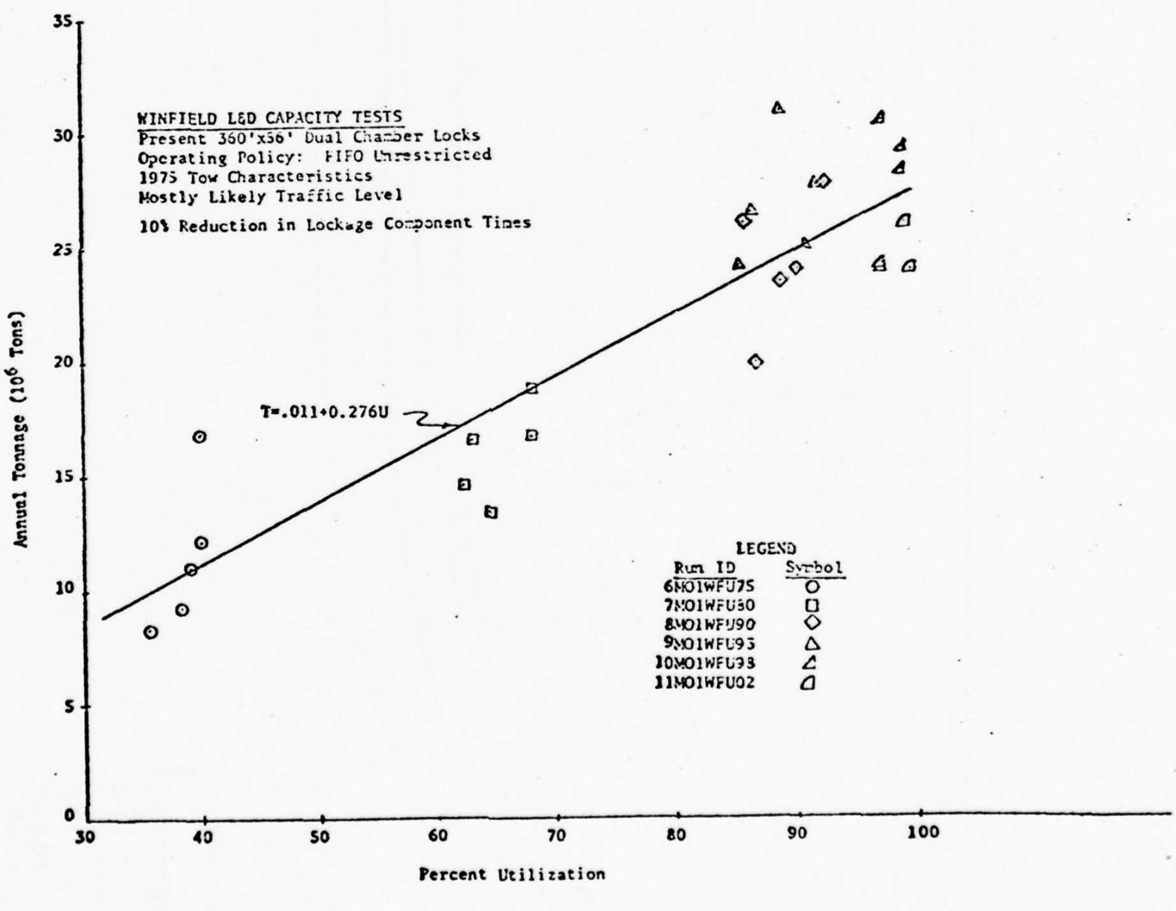

Figure 8. Annual Tonnage vs Utilization for the FIFO-Unrestricted Operating Policy with a 10% Reduction in Lockage Component Times

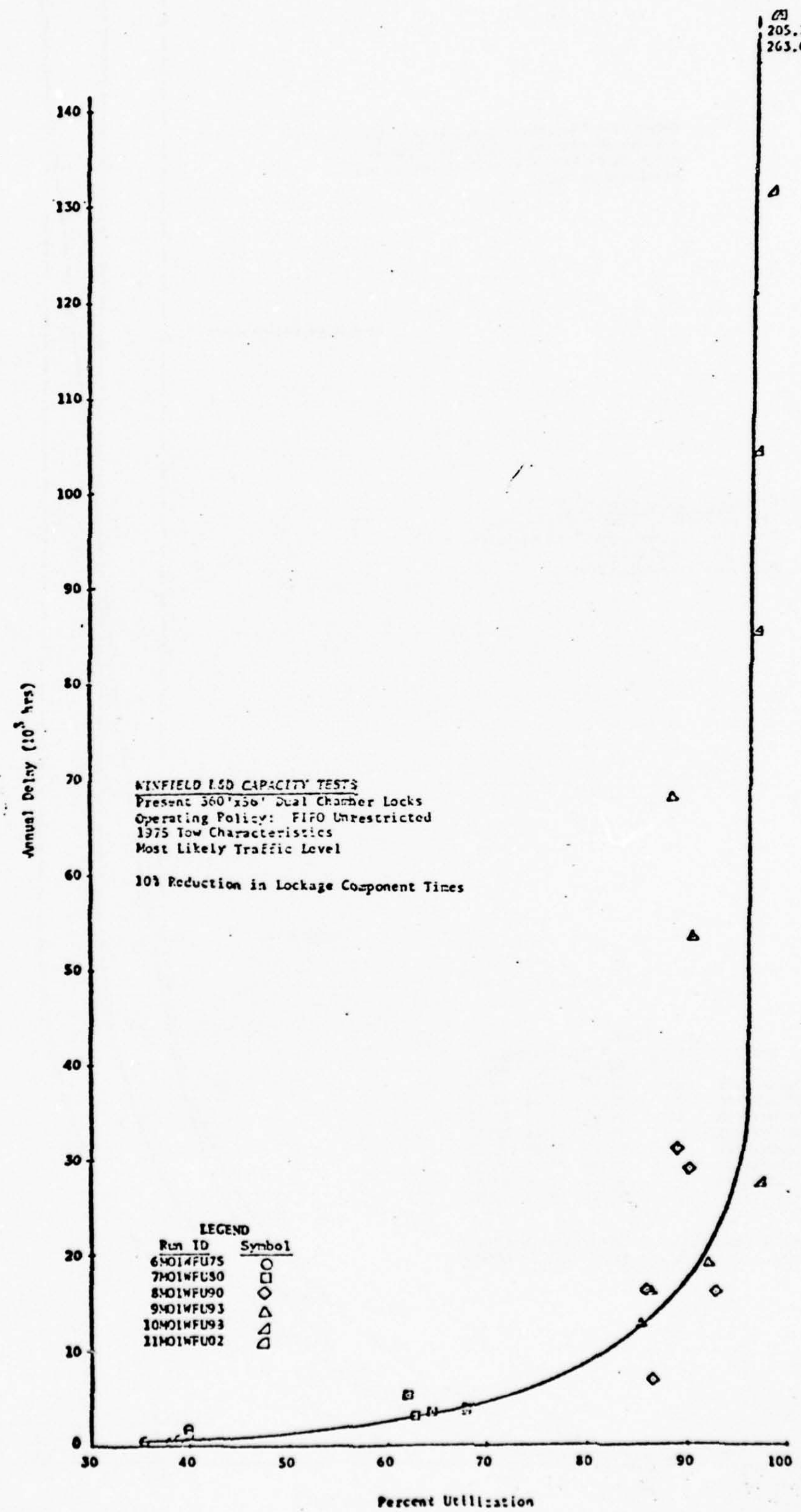

Figure 9. Annual Delay vs Utilization for the FIFO-Unrestricted Operating Policy with a 10% Reduction in Lockage Component Times

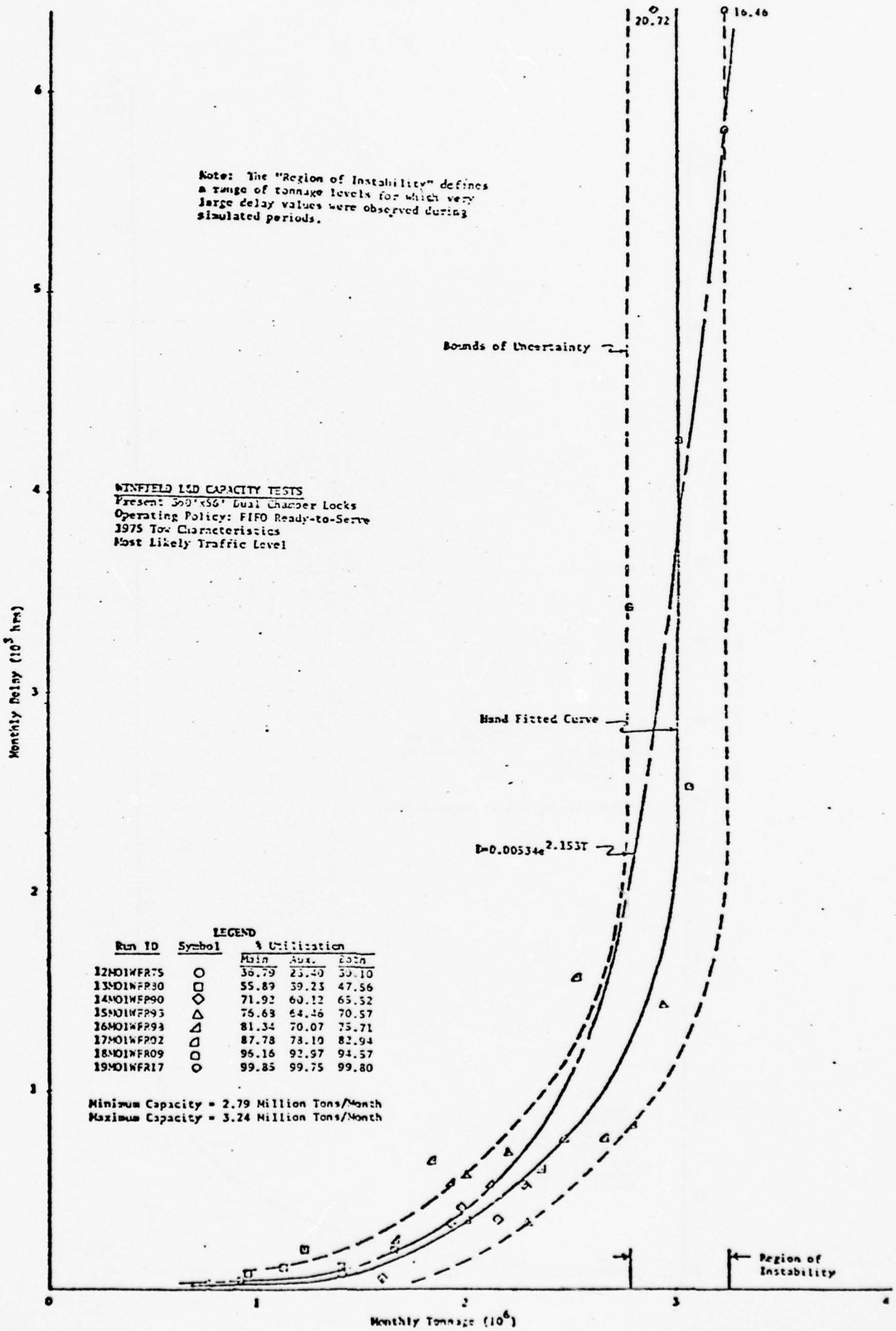

Figure 10. Monthly Delay vs Monthly Tonnage for the FIFO-Ready-to-Serve Operating Policy

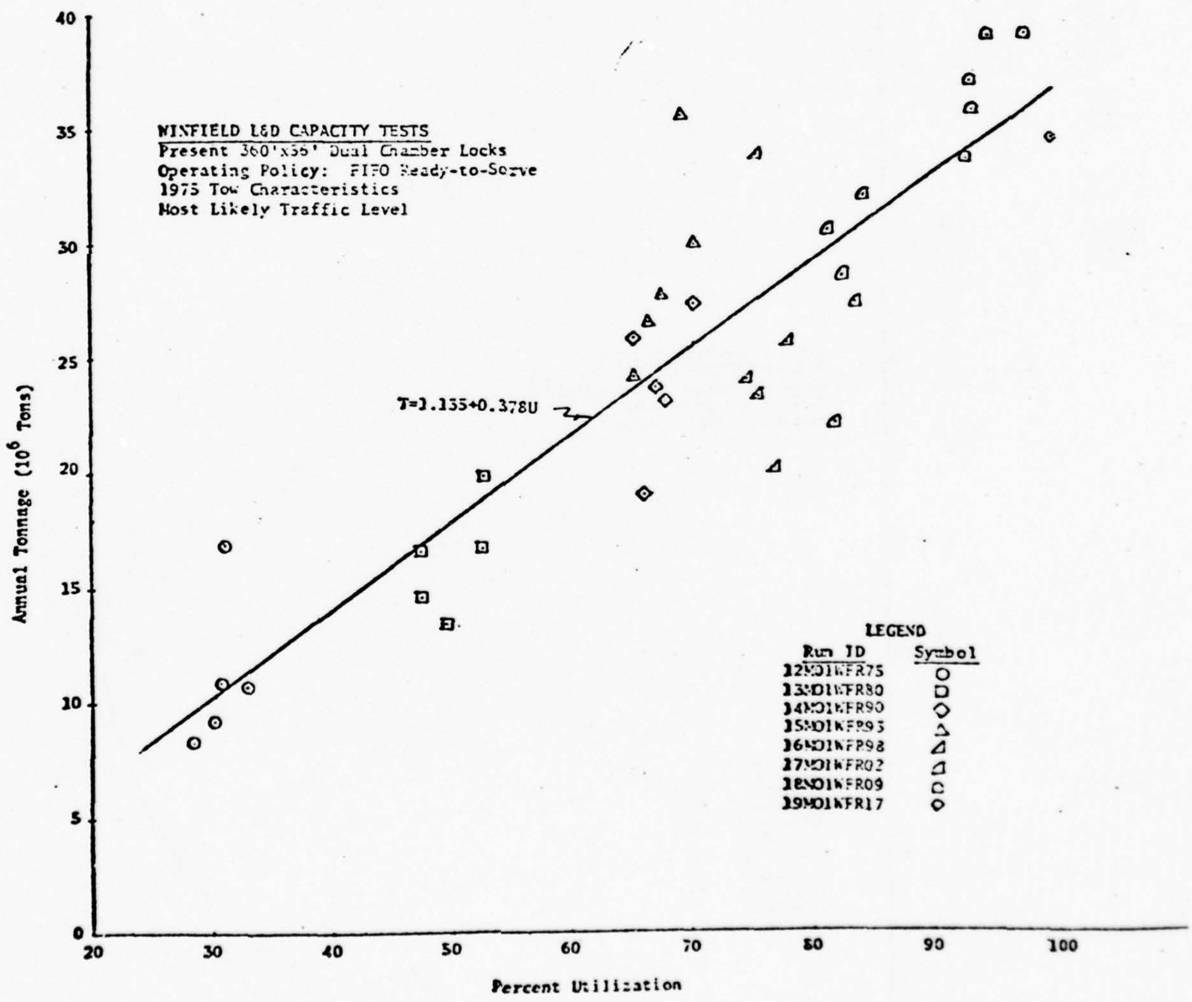

Figure 11. Annual Tonnage vs Utilization for the FIFO-Ready-to-Serve Operating Policy

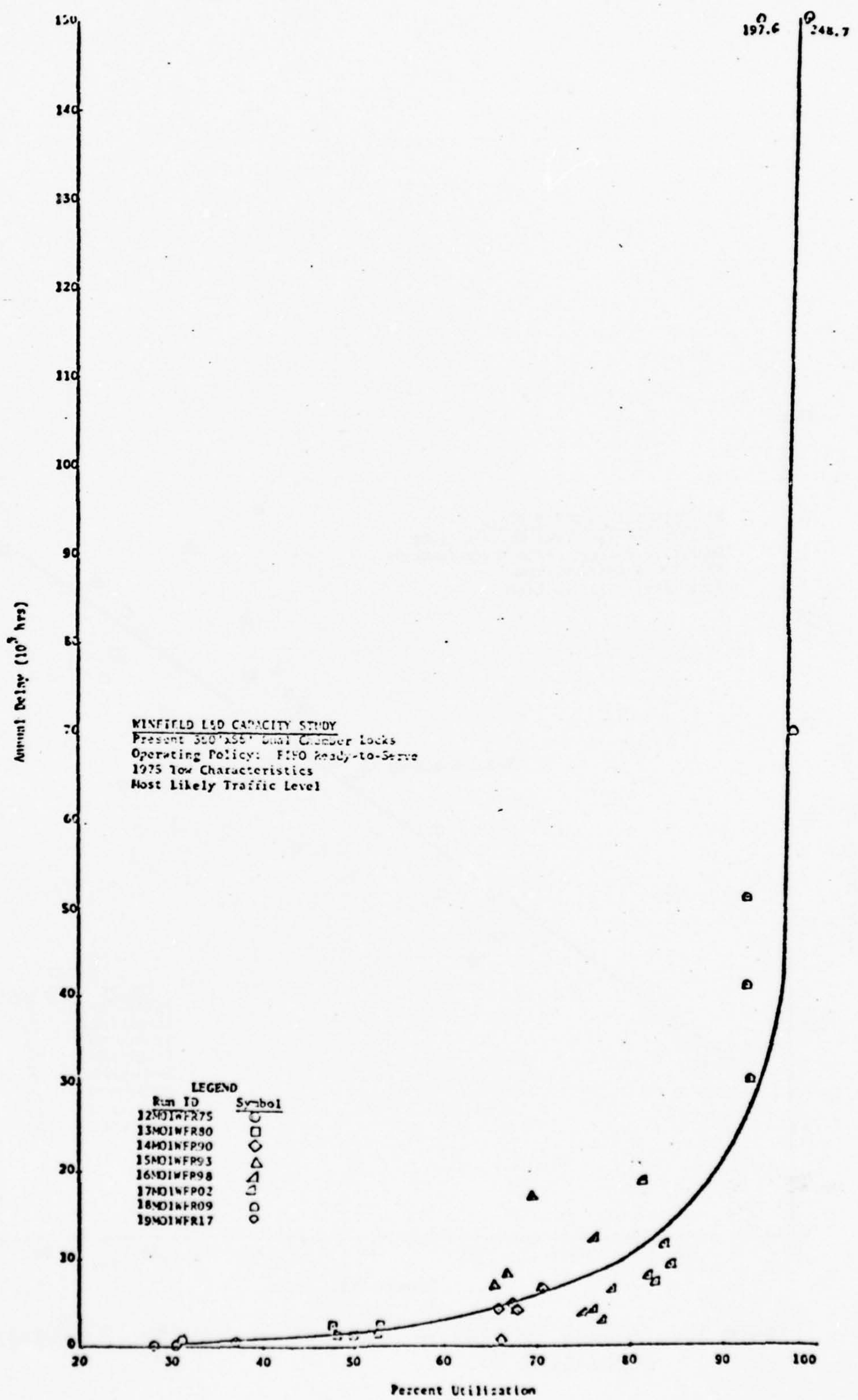

Figure 12. Annual Delay vs Utilization for the FIFO Ready-to-Serve Operating Policy

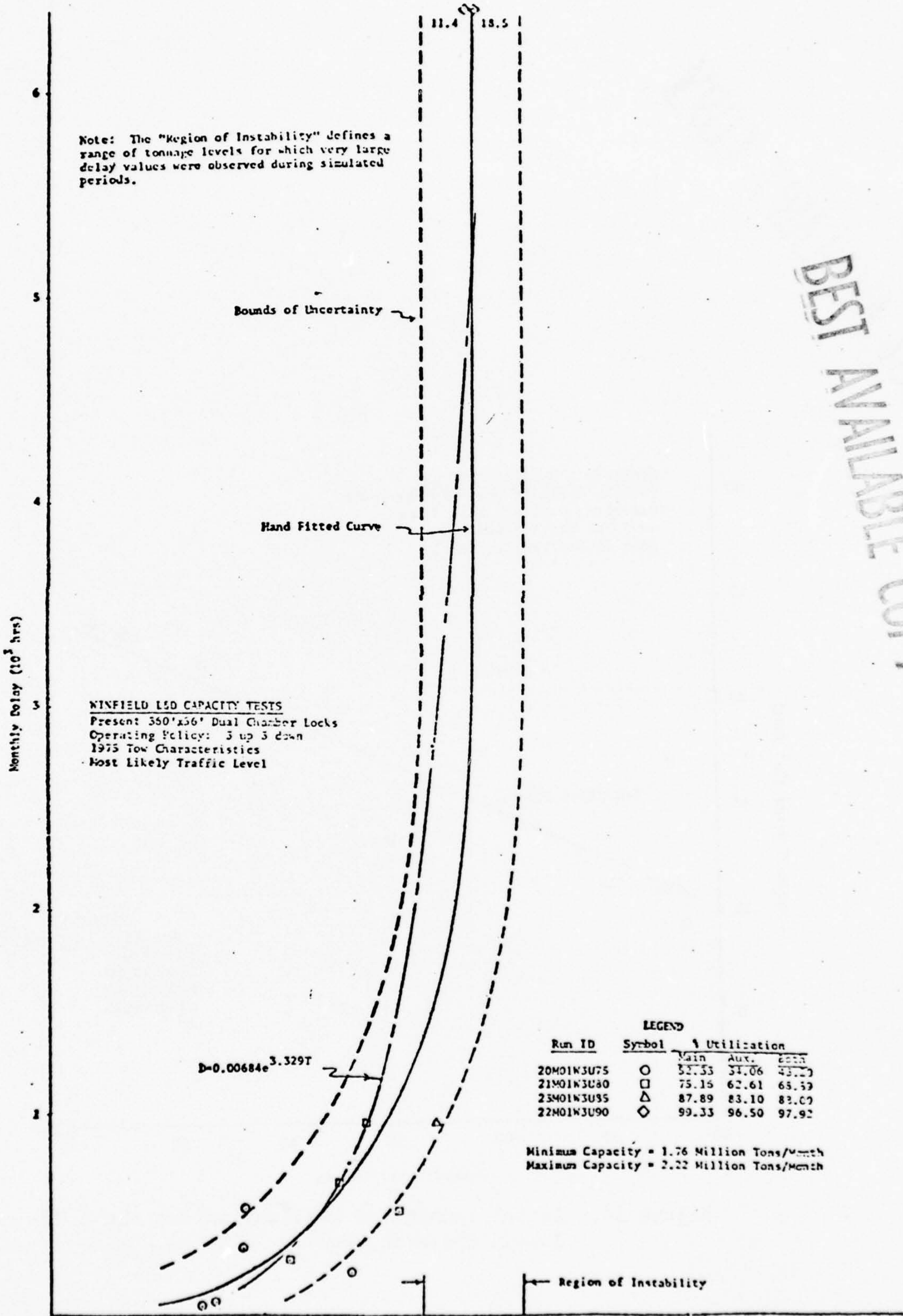

Figure 13. Monthly Delay vs Monthly Tonnage for the 3 Up-3 Down Operating Policy

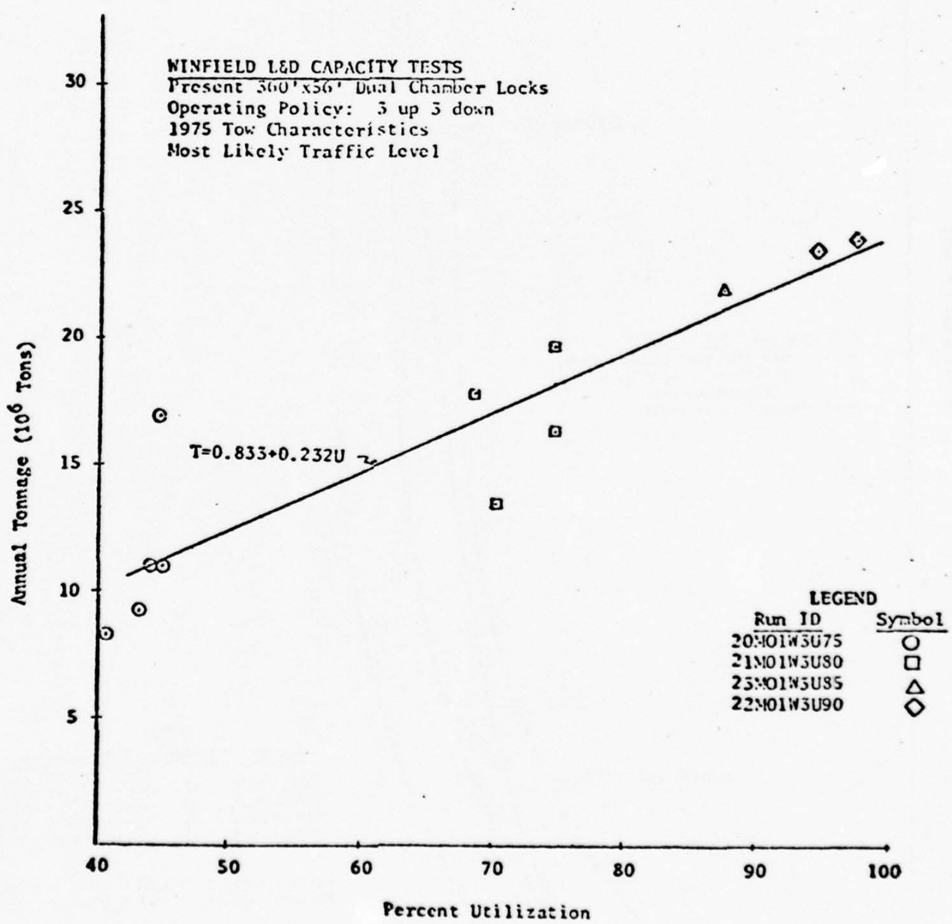

Figure 14. Annual Tonnage vs Utilization for the 3 Up-3 Down Operating Policy

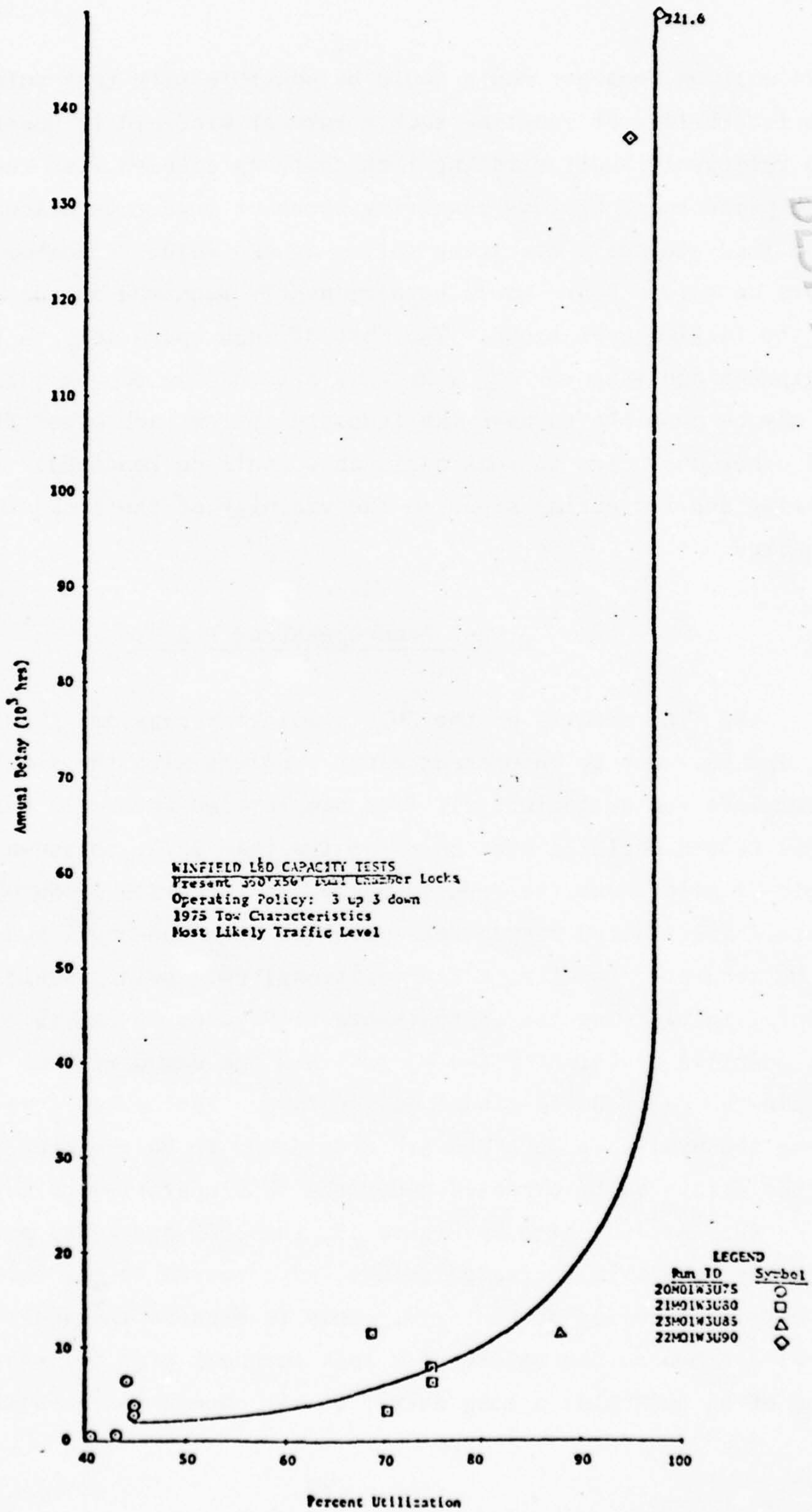

Figure 15. Annual Delay vs Utilization for the 3 Up-3 Down Operating Policy

3.24 million tons per month would be possible with this policy. However, the feasibility of adopting such a rule at Winfield is questionable. The relatively small existing lock chambers coupled with the exceptionally high percentages of tows requiring three or more cuts discourages the use of a ready-to-serve operating policy at Winfield. A number of switch-boats or helper boats would be permanently required at the locks to assist in the locking operations. The cost of such operations in terms of both equipment and manpower may make this alternative economically infeasible. It may be possible to have the industry assist each other if insurance and other obstacles to such assistance could be rendered. In any case, mooring and reflecting areas in the vicinity of the locks would be required.

3 Up-3 Down Operating Policy

48. The results of the 3U3D simulation runs are shown in Figures 13, 14, and 15. Due to unforeseen minor problems with the simulation model, a complete run to include all five sample time intervals for each tonnage level tested could be made only for the year 1975, as shown in Table C4. Table C4 also shows the reduced number of intervals produced for the other years. The limited sample data obtained from the model runs are considered to be accurate; however, a few additional data points would have been helpful in plotting the curves shown in Figures 13 and 15. Time did not permit a revision of the program and the computer runs required to obtain the desired additional data points. The curves were approximated using the available data and are considered to be reasonably representative of the delays to be expected under the 3U3D operating policy.

49. As indicated by Figure 13, the 3U3D operating policy would actually result in increased delays, as compared to the current FIFO-Unrestricted Policy at Winfield. This is because the small reduction in service times as the result of a lock turnback plus tow short entry, in lieu of an exit plus a long entry, is not enough to compensate for the

longer total waiting times inherent in the 3U3D operating policy. The longer waiting times are imposed on tows that arrived at the lock sooner than the tows being locked ahead of them. The tests of the 3U3D rule thus demonstrate that it is not a potential alternative operating policy for Winfield.

PART VII: CONCLUSIONS

50. Figure 16 graphically compares the annual tonnages and adjusted annual delays for each of the four alternative lock operating policies tested. These curves were constructed as described in Paragraphs 37-39 to take into consideration the small monthly variation in commodity movements at Winfield. Table 12 presents a tabular comparison and test summary for the four operating policies. If practical, the Ready-To-Serve policy would result in the most efficient use of the lock chambers themselves. However, due to the frequent need of several switchboats to assist large tows and the prevailing approach conditions at Winfield, the practicality of such a policy is questionable. Feasibility studies would be required before the Ready-to-Serve policy could be seriously considered as a potential means of increasing the locks' capacity. The 3U3D policy proved to be worse than FIFO mainly because of the present exceptionally long "short" entry times at the lock. (A "short" entry is usually possible when two or more tows traveling in the same direction are locked sequentially. The entering tow is permitted to tie to the guide wall only a short distance from the gates of the lock.) A number of factors such as the approach conditions, horsepower of towboats, tow lengths, type of cargo, river currents, and winds, among others, adversely influence entry times at Winfield, thus dictating that additional study would also be required for this alternative before it could be seriously considered as a potential operating policy. The FIFO, Unrestricted Policy with a 10 percent reduction in lockage component times would result in about a 6.4 percent and 6.7 percent increase in the minimum and maximum capacities, respectively, as compared with the FIFO, unrestricted policy using present lockage component times.

51. Although the physical capacity of the Winfield locks may not be reached in the near future, the economic capacity may have already been reached. Based on anticipated demands, traffic on the Kanawha River is expected to increase dramatically by 1980. However, this

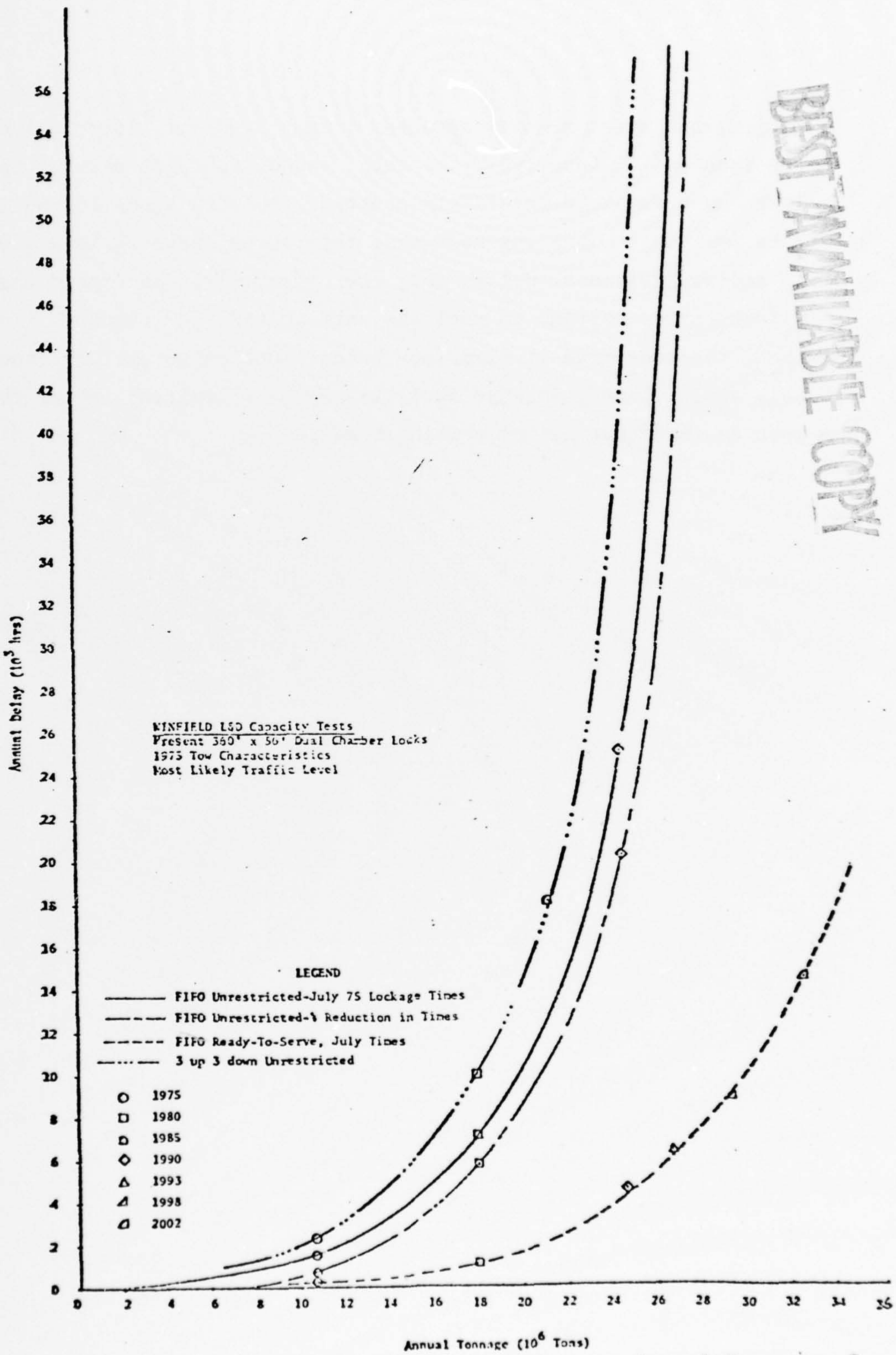

Figure 16. Comparison of Annual Delays vs Annual Tonnages for Four Different Lock Operating Policies

projection is not readily apparent from a study of historical data of the tonnages. Since 1967, the total annual tonnages passing through the locks have remained relatively constant, between about 10 and 12 million tons per year. This may mean that the towing industry is not willing to accept additional delays and, therefore, will not expand their waterborne operations to meet the anticipated requirements. In essence, then, the long transit times now being experienced by large tows at this small chamber lockage facility may be a limiting factor that is just as important as the waiting times.

TABLE 12

COMPARISON OF THE FOUR OPERATING POLICIES TESTED

Operating Policy	Cumulative Lock Utilization (%) 1975	1980	1990	Min. Limits (Million Tons/Mo)	Max. Limits (Million Tons/Mo)	Annual Tonnage 95% Utilization (Million Tons/Yr)
FIFO, Unrestricted	43.09	68.18	94.18	1.88	2.39	24.49
FIFO, Unrestricted (10% reduction in Lockage Component Times)	38.36	62.25	85.81	2.00	2.55	26.23
FIFO, Ready-To-Serve	30.10	47.56	65.52	2.79	3.24	34.78
3 Up-3 Down, Unrestricted	43.20	68.89	97.92	1.76	2.22	22.87

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2. Daggett, L. L. and Ankeny, T. D., "Determination of Lock Capacities Using Simulation Modeling," Miscellaneous Paper H-75-9, December 1975, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

APPENDIX A

FILE IDENTIFICATION CODES

APPENDIX A
FILE IDENTIFICATION CODES

The data generated by each WATSIM run was stored in permanent files under separate file names. Each file name has been coded to include: (a) Run number, (b) Commodity projection set number, (c) Lock system alternative, (d) Fleet characteristics, (e) Operating policy, and (f) Tonnage year. Each file name was coded as follows:

aaaabccdeeff

where

aaaa = Run number. Run numbers will be sequentially assigned and listed in a master run registration table which will contain all pertinent information on each computer run.

b = Commodity projection set code:

M for the most likely projection set

H for high projection set
L for low projection set } whichever is selected for testing

cc = Lock system alternative

01 for the existing system of locks

02 for dual 800'x110' locks at the current site

03 for dual 800'x110' locks at a new upstream site in the existing channel

04 for dual 800'x110' locks in a cutoff

05 for dual 1200'x110' locks or 600'x110', as necessary

06 for a single chamber lock of the size selected

07 for existing locks at Winfield and Gallipolis

08 for recommended replacement at Winfield and existing locks at Gallipolis

09 for replacement at Gallipolis and existing locks at Winfield

10 for proposed replacements at both Winfield and Gallipolis

d = Fleet characteristics

W for the current 1975 fleet characteristics at Winfield

G for currently observed tow makeups at Gallipolis shifting

F for future fleet characteristics that may make optimum use of the proposed lock sizes by 1990

ee = Operating policy code

FU for first in-first out (FIFO), unrestricted

FR for FIFO, ready to serve

1U for 1 up-1 down (flip-flop), unrestricted

3U for 3 up-3 down, unrestricted

ff = Tonnage year

75 for 1975

80 for 1980

90 for 1990

00 for 2000

10 for 2010

20 for 2020

30 for 2030

40 for 2040

APPENDIX B

SAMPLING PERIOD SENSITIVITY ANALYSIS

APPENDIX B
Sampling Period Sensitivity Analysis

1. The variation in monthly delays obtained from a given WATSIM run has been the subject of some concern. The procedure used to obtain monthly delays associated with a particular tonnage level and year is quite simple. The WATSIM program outputs delays in minutes and commodity movements in tons, together with a number of other pertinent data elements, for 10 separate 3-day periods (4,320 minutes) during a typical 30-day month. To get average monthly delays, any sampling period (or interval) length can be chosen and the associated delays increased linearly to approximate the delays during a 30-day month.

2. The decision was made to use five independent three-day sample periods in the Winfield Capacity Study to obtain monthly delays for each WATSIM run. The delays encountered during each period were simply multiplied by 10 and then divided by 60 to arrive at monthly totals in hours. The selected sample time periods are shown below:

Interval Beginning (Minutes from Run Initiation)	Interval Ending (Minutes from Run Initiation)
8640	12960
17280	21600
25920	30240
34560	38880
43200	47520

As shown above, there is no sample time interval overlap, e.g., the period from 8640 minutes to 12960 minutes is an entirely different period of simulation time than the period from 17280 minutes to 21600 minutes. An example of two overlapping time periods would be the intervals say from 8640 minutes to 21600 minutes and from 17280 minutes to 30240 minutes. Both sampling periods are 6 days in length but each includes delays associated with the other; i.e., the samples are not independent.

3. In addition to avoiding actual time overlaps in the sampled period, the choice of the intervals shown in the table above was also an attempt to avoid, to the extent possible, the often excessive delays associated with tows arriving during one 3-day period and not completing lockage until the next period. It is desirable to have independent sample periods. The simulation model does not add the statistics of any lockage to the lock's statistics until the lockage is completed. Thus when queue buildup during any one period occurs, the delay caused to tows arriving during this period but locking during the following period is added to the statistics for the following period. That is, there is some autocorrelation between sampling periods. In order to minimize this effect, a 3-day interval occurs between each of the above selected sample periods. For example, the 3-day period between 12960 minutes and 17280 minutes would be such an interval.

4. Unfortunately, however, even though the above rationale and logic were instrumental in choosing the five time intervals used, the variation in the computed monthly delay times was still significant, especially for future high tonnage years. As a result, a Sampling Period Sensitivity Analysis was performed for one high-level lock utilization run: the run using estimated 1993 tonnage levels with first in-first out (FIFO), unrestricted* operating policies. This run was partitioned into 6 different sample time interval sets for comparison of the monthly delay times obtained from each (see Table B1). Table B2 shows the variation in monthly delays for each sample interval within each set. For example, in Sample Set No. 1 monthly delays range from a low of 1,791 hours to a high of 13,256 hours. Sample Set No. 4 has the least variation between intervals. As shown in Table B2, the extreme high delays tend to occur during the last sample inverval, indicating the effects of major differences in the times between arrival of each

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* "Unrestricted" infers that tows may approach the lock chamber in the same configurations used between locks. That is, tows are not required to configure for the most efficient utilization of the lockage facilities. This is the operating policy used at Winfield today.

tow (interarrival times) and the service times. During high lock utilization, tows arrive much too often to be serviced without long delays. The queues continue to build under these conditions as lock operations are simulated over a period of time. Toward the end of the simulation period (1 month in this case), queues and delay times have increased to the point where tonnage throughput increases vary little, if any, along with the extremely high rate of increase in delays.

5. The results of the Sampling Period Sensitivity Analysis indicated that large variatons in monthly delay times will usually occur during periods of high lock utilization, regardless of the sample interval selected. The sample intervals of three-days length used in the Winfield analysis are, therefore, considered to be of an adequate length.

6. It is believed that a major part of the variation observed in the sampled data for the Winfield Locks is due to the wide range in the number of cuts required for lockage and hence the wide range of lockage times required to service various tows. Thus, in any one sampling period the tonnage levels may not vary much but the number of tows serviced may vary significantly. Any tows present would incur large delay times if several tows requiring many cuts were serviced during the sampling period, while the delays incurred during another sampling period could be quite short if only singles and doubled were serviced during that period. All this could occur while the tonnage processed during these sampling periods would not vary by a large amount.

TABLE B1

Sampling Period Sensitivity Analysis
Formulation of Sample Interval Sets Tested

The six time period sets are given below in schematic form. Each interval is bracketed and numbered, and the multiplier used to adjust each associated delay to a 30-day month is shown in Note C.

<u>Sample Interval Set No. 1</u>

	8640
1	12960
	17280
2	21600
	25920
3	30240
	34560
4	38880
	43200
	47520

Note:
A. Four 8640-minute intervals
B. 8640 minutes = 6 days = 0.2 month
C. Delays during each 6-day period times 5 = monthly delays

<u>Sample Interval Set No. 2</u>

	8640
1	12960
	17280
	21600
2	25920
	30240
	34560
3	38880
	43200
	47520

Note:
A. Three 12960-minute intervals
B. 12960 minutes = 9 days = 0.30 month
C. Delays during each 9-day period times 3.33 = monthly delays

TABLE B1 (continued)

Sample Interval Set No. 3

	8640
	12960
1	17280
	21600
	25920
	30240
	34560
2	38880
	43200
	47520

Note: A. Two 17280-minute intervals

B. 17280 minutes = 12 days = 0.40 month

C. Delays during each 12-day period times 2.5 = monthly delays

Sample Interval Set No. 4

	8640
	1296
	17280
	21600=
1	25920
2	30240
3	34560
	38880
	43200
	47520

Note: A. Three 30240-minute intervals

B. 30240 minutes = 21 day = 0.70 month

C. Delays during each 21-day period times 1.43 = monthly delays

Sample Interval Set No. 5

	8640
	12960
	17280
	21600
	25920
1	30240
	34560
	38880
	43200
	47520

Note: A. One 38880-minute interval

B. 38880 minutes = 27 days = 0.90 month

C. Delays during each 27-day period times 1.11 = monthly delays

Sample Interval Set No. 6

	8640
1	12960
	17280
2	21600
	25920
3	30240
	34560
	38880
4	43200
	47520

Note: A. Four 12960-minute intervals

B. 12960 minutes = 9 days = 0.30 month

C. Delays during each 9-day period times 3.33 = monthly delays

TABLE B2

Sampling Period Sensitivity Analysis
Delays and Associated Tonnages for Each Sample Interval Set
(1993 FIFO - Unrestricted Run)

Sample Interval Set No.	Year (Sample Interval)	Monthly Delay (hrs)	Monthly Tonnage (K tons)
1	1993		
	(1)	3,038	2,094
	(2)	1,791	1,844
	(3)	3,672	2,013
	(4)	13,256	2,278
2	1993		
	(1)	2,620	2,135
	(2)	3,041	1,828
	(3)	15,157	2,134
3	1993		
	(1)	2,414	1,969
	(2)	12,725	2,106
4	1993		
	(1)	3,920	2,049
	(2)	5,723	2,019
	(3)	8,072	2,050
5	1993		
	(1)	6,877	2,014
6	1993		
	(1)	2,620	2,135
	(2)	1,846	1,898
	(3)	5,913	2,148
	(4)	15,157	2,134

APPENDIX C

REDUCED WATSIM DATA FOR FOUR ALTERNATIVE OPERATING POLICIES AT THE EXISTING WINFIELD LOCKS

TABLE C1

WINFIELD L&D CAPACITY TESTS

Present 360'x56' Dual Chamber Locks
Most Likely Traffic Level
1975 Tow Characteristics
Operating Policy: FIFO Unrestricted

Year	(Sample No.)	No. of Tows Per Month (Main & Aux)	Monthly Delay (hrs)	Monthly Tonnage (K tons)	Annual Delay (hrs)	Annual Tonnage (K tons)	Percent Utilization Cham. A	Cham. B	Lock
1975	(1)	360	111	900	1,328	10,799	55.24	34.10	44.67
	(2)	270	70	695	840	8,339	51.21	30.90	41.06
	(3)	380	147	1,017	1,760	12,203	53.54	34.95	44.25
	(4)	400	303	1,412	3,638	16,938	53.51	36.23	44.87
	(5)	320	57	774	678	9,290	51.25	34.81	43.09
1980	(1)	510	495	1,356	5,934	16,273	80.75	70.51	75.63
	(2)	490	482	1,559	5,780	18,707	81.24	70.09	75.67
	(3)	480	254	1,116	3,042	13,388	78.40	63.95	71.18
	(4)	510	315	1,406	3,774	16,868	77.43	60.31	68.87
	(5)	530	513	1,152	6,152	13,585	75.90	60.45	68.18
1990	(1)	740	3,590	1,848	43,076	22,172	95.91	97.99	96.95
	(2)	750	6,890	2,372	82,684	28,459	97.85	98.29	98.07
	(3)	760	5,139	2,103	61,672	25,240	97.54	96.78	97.16
	(4)	650	3,225	1,831	38,700	21,976	95.27	93.40	94.34
	(5)	660	2,845	2,190	34,144	26,276	95.25	93.11	94.18
1993[1]	(1)	750	3,496	2,120	41,952	25,440	96.47	91.43	93.95
	(2)	780	1,793	2,223	21,518	26,680	97.27	91.88	94.58
	(3)	690	1,963	2,012	23,556	24,142	97.43	90.96	94.20
	(4)	820	10,413	2,427	124,958	29,118	98.03	93.06	95.55
	(5)	700	19,006	1,854	228,076	22,242	97.74	94.16	95.95
1998[2]	(1)	740	18,252	2,153	219,022	25,837	99.42	100.00	99.71
	(2)	Infinite Queuing at time 16,970 minutes							

[1]Estimated using 1990 projections and divisors of 11.0 in TOWGEN for each commodity.
[2]Estimated using 1990 projections and divisors of 10.0 in TOWGEN for each commodity.

TABLE C2

WINFIELD L&D CAPACITY TESTS
Present 360'x56' Dual Chamber Locks
Most Likely Traffic Level
1975 Tow Characteristics
Operating Policy: FIFO Unrestricted w/10% Reduction in Lockage Component Times

Year	(Sample No.)	No. of Tows Per Month (Main & Aux)	Monthly Delay (hrs)	Monthly Tonnage (K tons)	Annual Delay (hrs)	Annual Tonnage (K tons)	Percent Utilization Cham. A	Percent Utilization Cham. B	Percent Utilization Lock
1975	(1)	360	62	900	744	10,799	48.74	29.16	38.95
	(2)	270	40	695	480	8,339	45.45	25.44	35.45
	(3)	370	92	1,017	1,106	12,203	46.73	32.94	39.84
	(4)	400	141	1,412	1,696	16,938	46.39	33.36	39.88
	(5)	320	37	774	438	9,290	44.42	32.29	38.36
1980	(1)	520	303	1,398	3,634	16,771	75.37	60.31	67.84
	(2)	480	313	1,559	3,756	18,707	75.48	61.05	68.27
	(3)	480	284	1,116	3,410	13,388	72.11	56.76	64.44
	(4)	500	257	1,385	3,078	16,625	70.66	54.87	62.77
	(5)	550	440	1,215	5,274	14,581	69.31	55.19	62.25
1990	(1)	790	2,610	1,950	31,322	23,394	92.37	85.29	88.83
	(2)	810	1,334	2,311	16,002	27,731	94.63	90.94	92.79
	(3)	730	2,425	2,003	29,098	24,037	93.16	87.52	90.34
	(4)	590	578	1,651	6,940	19,817	89.81	83.51	86.66
	(5)	710	1,359	2,174	16,312	26,090	88.82	82.80	85.81
1993*	(1)	850	1,586	2,309	19,034	27,712	93.10	90.96	92.03
	(2)	770	1,362	2,210	16,340	26,519	89.00	84.10	86.55
	(3)	690	1,064	2,012	12,772	24,142	88.31	82.66	85.49
	(4)	880	5,689	2,571	68,272	30,852	90.87	86.62	88.75
	(5)	790	4,463	2,089	53,558	25,063	92.51	88.94	90.73
1998*	(1)	860	10,979	2,437	131,750	29,245	99.76	98.85	99.31
	(2)	890	13,138	2,356	157,652	28,272	99.37	99.29	99.33
	(3)	760	2,285	2,018	27,424	24,210	98.05	97.37	97.71
	(4)	830	8,713	2,548	104,556	30,578	98.01	97.14	97.58
	(5)	810	7,127	1,993	85,524	23,910	98.06	97.42	97.74
2002*	(1)	840	17,097	2,161	205,162	25,934	99.09	99.57	99.33
	(2)	860	21,963	1,997	263,560	23,960	99.46	100.00	99.73
	(3)	Infinite queuing at 29,827 minutes.							

*Tonnage levels in TOWGEN for these years were estimated by using 1990 projections and commodity tonnage divisors of 11.0, 10.0, and 9.0 for 1993, 1998, and 2002, respectively.

TABLE C3

WINFIELD L&D CAPACITY TESTS
Present 360'x56' Dual Chamber Locks
Most Likely Traffic Level
1975 Tow Characteristics
Operating Policy: FIFO Ready-To-Serve

Year (Sample No.)		No. of Tows Per Month (Main & Aux)	Monthly Delay (hrs)	Monthly Tonnage (K tons)	Annual Delay (hrs)	Annual Tonnage (K tons)	Percent Utilization		
							Cham. A	Cham. B	Lock
1975	(1)	360	27	900	322	10,799	38.08	22.53	30.31
	(2)	270	20	695	240	8,339	36.85	19.64	28.25
	(3)	360	42	915	508	10,985	37.94	23.39	30.67
	(4)	400	69	1,412	832	16,938	38.00	24.26	31.13
	(5)	320	25	774	298	9,290	36.79	23.40	30.10
1980	(1)	520	106	1,398	1,274	16,771	60.75	44.62	52.69
	(2)	520	194	1,659	2,326	19,902	58.28	47.46	52.87
	(3)	480	111	1,116	1,328	13,388	56.94	42.48	49.71
	(4)	490	80	956	1,385	16,625	56.52	39.85	48.19
	(5)	550	204	1,215	2,444	14,581	55.89	39.23	47.56
1990	(1)	770	413	1,976	4,954	23,708	72.24	62.52	67.38
	(2)	800	525	2,278	6,304	27,332	77.09	64.15	70.62
	(3)	680	330	1,927	3,962	23,118	75.01	61.26	68.14
	(4)	540	44	1,595	522	19,139	72.74	59.59	66.17
	(5)	700	345	2,158	4,146	25,891	71.92	60.12	65.52
1993	(1)	850	327	2,309	3,920	27,712	74.48	61.19	67.84
	(2)	770	682	2,210	8,178	26,519	73.37	60.07	66.72
	(3)	690	568	2,012	6,810	24,142	71.92	59.01	65.47
	(4)	1,000	1,427	2,954	17,122	35,448	75.95	63.23	69.59
	(5)	910	530	2,287	6,354	27,440	76.68	64.46	70.57
1998	(1)	760	532	2,137	6,392	25,640	81.44	74.94	78.19
	(2)	670	224	1,670	2,692	20,035	83.14	70.97	77.06
	(3)	780	320	2,011	3,842	24,136	80.72	69.06	74.89
	(4)	890	1,014	2,813	12,168	33,757	81.79	70.01	75.90
	(5)	780	332	1,938	3,988	23,252	81.34	70.07	75.71

TABLE C3 (Continued)

Year (Sample No.)		No. of Tows Per Month (Main & Aux)	Monthly Delay (hrs)	Monthly Tonnage (K tons)	Annual Delay (hrs)	Annual Tonnage (K tons)	Percent Utilization		
							Cham. A	Cham. B	Lock
2002	(1)	930	766	2,669	9,194	32,028	90.32	78.57	84.45
	(2)	830	654	1,845	7,842	22,136	87.21	76.80	82.01
	(3)	960	1,569	2,538	18,824	30,451	86.41	76.85	81.63
	(4)	910	956	2,278	11,474	27,338	87.99	79.71	83.85
	(5)	790	600	2,373	7,200	28,475	87.78	78.10	82.94
2009	(1)	1,070	5,807	3,253	69,682	39,034	98.68	96.72	97.70
	(2)	1,080	3,421	2,803	41,046	33,640	95.42	90.36	92.89
	(3)	1,080	2,526	3,082	30,310	36,988	95.55	90.73	93.14
	(4)	1,160	4,250	3,029	51,004	36,346	95.36	91.25	93.31
	(5)	1,070	16,463	3,244	197,558	38,928	96.16	92.97	94.57
2017	(1)	1,120	20,724	2,912	248,686	34,944	99.85	99.75	99.80
	(2)	Infinite Queuing at Time 17393 minutes.							

TABLE C4

WINFIELD L&D CAPACITY TESTS

Present 360'x56' Dual Chamber Locks
Most Likely Traffic Level
1975 Tow Characteristics
Operating Policy: 3 up-3 down, Unrestricted

Year	(Sample No.)	No. of Tows Per Month (Main & Aux)	Monthly Delay (hrs)	Monthly Tonnage (K tons)	Annual Delay (hrs)	Annual Tonnage (K tons)	Percent Utilization Cham. A	Cham. B	Lock
1975	(1)	360	331	900	3,976	10,799	56.59	33.43	45.01
	(2)	270	42	694	500	8,332	52.09	29.01	40.55
	(3)	380	525	915	6,294	10,985	54.87	33.57	44.22
	(4)	400	212	1,412	2,540	16,938	53.95	35.76	44.86
	(5)	320	65	774	774	9,290	52.33	34.06	43.20
1980	(1)	510	650	1,356	7,802	16,273	79.73	70.37	75.05
	(2)	520	517	1,639	6,208	19,664	78.63	71.41	75.02
	(3)	480	276	1,116	3,312	13,388	76.01	64.79	70.40
	(4)	490	952	1,491	11,420	17,897	75.16	62.61	68.89
1985	(1)	680	945	1,810	11,340	21,720	87.89	88.10	88.00
1990	(1)	710	11,407	1,959	136,884	23,503	97.34	92.43	94.89
	(2)	710	18,466	1,995	221,590	23,936	99.33	96.50	97.92
	(3)	Infinite Queuing occurs at Time 28,737 minutes.							

APPENDIX D

TONNAGE PROJECTION METHOD COMPARISON ANALYSIS

APPENDIX D

Tonnage Projection Method Comparison Analysis

1. Only historical commodity tonnage data for 1975 and projected tonnages for 1980 and 1990 were available for use in the Winfield Lock capacity studies. Although high lock utilization percentages occur for the 1990 tonnages using two of the alternative lock operating procedures, the 1990 tonnages are not great enough to cause infinite queuing. Thus, a decision was made to increase tonnage levels beyond the year 1990 by keeping the relative distribution of commodities constant at any given tonnage level with the ratio being the same as the projected 1990 distribution. To accomplish this, tonnage divisors of 11.0, 10.0, 9.0, 8.0, and 7.0, respectively, were used in TOWGEN for producing more tows per month for input to WATSIM.

2. The tonnage divisors in TOWGEN work in the following manner to create more tonnage passing through the lock, and thus more tows. Annual tonnages by commodity and direction are input to TOWGEN. If the projected tonnages for a given year, say 1990, are available, these are input directly to TOWGEN together with a divisor of 12.0 for each commodity. This in effect divides the resulting tow list by 12 and outputs a list of tows to be processed by the lock during a typical month. A tonnage divisor less than 12.0 for each commodity produces more tonnage by dividing the input tonnages by a smaller number. For example, annual tonnage level of 25,000 tons for a given commodity would be equivalent to 25,000 ÷ 12 or 2083 tons per month; whereas, dividing 25,000 tons by 11 would be 2273 tons per month. The tonnage divisor feature is usually used to compute monthly tonnages that are not equally distributed throughout the year.

3. The purpose of this appendix is to briefly compare the tonnage divisor method of projecting tonnages with a linear trend procedure based on expected increases and decreases in the six commodity groups

between 1980 and 1990. Table D1 shows a comparison of tonnage projections by commodity for these two methods. The following is a column by column description of Table D1:

a. Column 1 - The six commodity groupings in the Winfield Capacity Study.

b. Columns 2 and 3 - Projected tonnage levels for the years 1980 and 1990 as provided by the Huntington District (ORHED-PE).

c. Column 4 - Increases and decreases in tonnages by commodity type during the period 1980 to 1990.

d. Column 5 - Linear change in tonnages by year for the 10-year period, i.e., each tonnage in Column 4 divided by 10.

e. Column 6 - The percent each commodity either increases or decreases during each year of the decade is derived by simply dividing the tonnage change for each commodity group as shown in Column 5 by the total change shown at the bottom of Column 5.

f. Column 7 - These are the tonnages obtained by using the tonnage divisor 11.0. The 1990 commodity tonnages are each divided by 11.0 and then multiplied by 12.0 to obtain an increased annual tonnage for each commodity.

g. Column 8 - This column simply shows the increase in total tonnage between 1990 and the level obtained by using a divisor of 11.0.

h. Column 9 - This is the number of years growth represented by the tonnage increase shown in Column 8. The 3.4 years is related to the 1980 to 1990 trend of total expected tonnage increase by dividing the tonnage in Column 8 by the average growth during this decade.

i. Column 10 - The 3.4 years equivalent growth is multiplied by the tonnages for each commodity group in Column 5 to determine commodity increases and decreases for this period based on the 1980 to 1990 trend.

j. Column 11 - The year 1993.4 is truncated to be 1993. Linear tonnage changes during this period based on the 1980 to 1990 trend are added to the 1990 levels to obtain the 1993 tonnages for comparison with Column 7.

k. Column 12 - This shows the differences in the tonnages obtained by using the two projection techniques.

4. Using trend increases, 246,000 more tons of chemicals would have been used as input to TOWGEN and 189,000 and 69,000 less tons of aggregates and coal, respectively. These are the major differences in the two projection methods. While differences in tonnages provided by the two techniques described above might be considered significant, considering the lock utilization and delay times obtained from a test WATSIM run, there did not appear to be any significant effect on the determination of the locks' capacity. Based on the results of this analysis, it was not considered necessary or fruitfui to make additional WATSIM runs to determine delays associated with other projected tonnage levels beyond 1990. The subject of tonnage projections is discussed further in the main text of this report.

TABLE D1

Tonnage Projection Method Sensitivity Analysis

Commodity	Projected Tonnages (K Tons) 1980	1990	Difference Col 3 Minus Col 2 (K Tons)	Linear Tonnage Change/yr (Diff ÷ 10) (K Tons)	% Change Each Commodity	Projected Tonnage Using Divisor=11.0 (K Tons)	Total Col 7 Minus Total Col 3 (K Tns)	Col 8 ÷ Col 5 Total (years)	Tonnage Changes 1990 to 1993 Col 5 x 3.4 (K Tons)	1993 Tonnages Col 3 + Col 10 (K Tons)	Diff in Projection Methods Col 7 Minus Col 11 (K Tons)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Coal	7252	9626	2374	237.4	36.4	10,501	-	-	807.2	10433	68
Chemicals	6732	10177	3445	344.5	52.82	11,102	-	-	1171.3	11348	-246
Aggregates	1952	1903	-49	-4.9	-0.75	2,075	-	-	-16.7	1886	189
Petroleum	1166	1576	410	41.0	6.29	1,719	-	-	139.4	1715	4
Other	691	1038	347	34.7	5.32	1,132	-	-	118.0	1156	-24
Cement	173	168	-5	-0.5	-0.08	183	-	-	-1.7	166	17
TOTAL	17966	24488	6522	652.2	100.0%	26,712	2,224	3.4*	2217.5	26705	+7

*Thus equating to 1990 + 3.4 years = 1993.4 and truncated to the whole year 1993.

APPENDIX E

DEFINITIONS

APPENDIX E
Definitions

Specialized terms used in this report are defined below:

1. Chambering: The filling or emptying of the lock chamber with one or more vessels in the chamber.

2. Chambering time: The time period beginning when the bow of the vessel being served crosses the sill upon entry to the lock chamber and ending when the stern of the power unit, or towboat, crosses the opposite sill upon exiting the chamber. For multi-cut lockages and jackknife, knockout and setover lockages, this time includes the time required to break the tow upon entry to the lock, remake the tow upon exiting and for processing all intermediate cuts of multi-cut lockage, including the turnback times.

3. Cut: That portion of a tow that can be contained within the lock chamber for chambering.

4. Dedicated equipment: The exclusive use of a towboat and particularly the barges to transport only one type of commodity. The greater the percentage of dedicated equipment, the greater the number of empty backhaul barges.

5. Double lockage: The lockage of a tow larger than the lock via two distinct lockages.

6. Double knockout, double setover, or double jackknife lockage: One cut of a double lockage must either be a knockout, setover, or jackknife type lockage in order to permit the passage of the tow in only two lockages. (See definitions of knockout, setover, and jackknife lockages below.)

7. Downstream approach: The reach of river immediately downstream from the lockage facility and dam leading to the lock chamber entrance.

8. Exit time: The period in minutes beginning when the stern of the exiting towboat crosses the sill on exit and ending when the tow passes the defined approach point or the next entering tow, whichever occurs first.

9. First In, First Out (FIFO), Unrestricted Operating Policy: The tows are serviced in the order of their arrival and no restriction is placed on the barge configuration (tow makeup) or size as they approach the lock, i.e., no remake or reconfiguration of the barges is required prior to beginning the lockage process.

10. First In, First Out (FIFO) Ready-to-Serve Operating Policy: Same as the FIFO Unrestricted Policy except it prohibits the breaking or remaking of tows in the vicinity of or within a lock chamber.

11. Fleet characteristics: The general makeup of tows in a particular river reach as pertains to boat horsepower, number of barges, barge types and sizes, flotilla configuration, etc.

12. Fly entry: A fly entry occurs when the lock is idle when an inbound vessel arrives at the lock and is the period of time beginning when the vessel passes the approach point and ending when the vessel's bow crosses the sill upon entering the lock chamber.

13. Integrated barge: A single unit of barges made up of two or more barges which are usually left connected together to form the integrated barge. A wide variety of barge sizes exists for the barges used in this manner. Most integrated barges are tank barges and are used in a dedicated manner.

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CAPACITY STUDIES OF WINFIELD LOCKS, KANAWHA RIVER, WEST VIRGINI--ETC(U)
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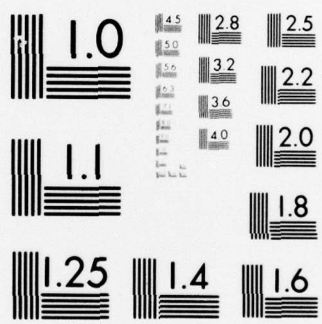

MICROCOPY RESOLUTION TEST CHART

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14. Jackknife lockage: The tow is rearranged, e.g., from two barges wide to three, by breaking the face couplings on at least two barges and the side couplings on at least one barge.

15. Jumbo barge: A regular long jumbo barge either 195 or 200 ft long and 35 ft wide.

16. Knockout lockage: The towboat alone is separated from its barges to be "set over" for service.

17. Lockage: The passage of a vessel through the lock facility.

18. Lockage component: One of the sequences of events involved in the locking process. These include various types of tow entries, chamberings, and exits.

19. Lockage types: Lockage types include straight singles, doubles, triples, etc., along with setovers, jackknifes, knockouts, multivessel lockages, and others.

20. Mixed barge tows: A tow consisting of more than one barge type.

21. Multi-cut lockage: A lockage requiring two or more straight cuts, e.g., double, triple, quadruple, etc.

22. Multiple entry: The entry of two or more relatively small tows to be locked together in a single lockage.

23. Multiple exit: The exit of two or more relatively small tows following their being locked together in a single lockage.

24. Multiple tow lockage: More than one vessel or tow is served in a single chambering.

25. Open-pass lockage: The vessel transverses the lock with no lock hardware operation.

26. Performance Monitoring System (PMS): A system developed by the U. S. Army Corps of Engineers to measure the service which the inland waterways provide to the navigation industry. It has been implemented at Corps inland navigation facilities within the U. S. and provides planners and operations' personnel with data and complete programs needed for analysis of the operation of the inland and intracoastal navigation systems.

27. Queue: A group of one or more tows waiting to be serviced by the lock.

28. Regular barge: A small regular barge 175 ft long and 26 ft wide.

29. Setover lockage: The towboat and one or more of its barges are separated from the remaining barges to be "set over" for service.

30. Single lockage: The tow is not broken up for lockage.

31. Turnback: The filling or emptying of the lock chamber required to service the next cut of a multi-cut lockage tow or another tow traveling in the same direction.

32. Turnback entry: An entry following a lock turnback during which no vessel was served and in which the vessel to be locked had arrived prior to the exit of the previous vessel being locked.

33. Tow processing time: The total time in minutes required for a tow to be served by a lock. This time begins when the tow is signaled to enter the lock and ends upon completion of the exit.

34. Three up-three down operating policy: Three vessels traveling in the same direction are locked sequentially, followed by the sequential lockage of three vessels traveling in the opposite direction or until all vessels in a queue are served, whichever occurs first.

35. Upstream approach: The reach of the river immediately upstream from the lockage facility and dam leading to the lock chamber entrance.

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Daggett, Larry L
Capacity studies of Winfield Locks, Kanawha River, West Virginia, by Larry L. Daggett [and] Robert W. McCarley. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1977.
1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Miscellaneous paper H-77-1)
Prepared for U. S. Army Engineer District, Huntington, Huntington, W. Va.
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1. Computerized simulation. 2. Inland waterways. 3. Locks (Waterways). 4. Gallipolis Lock & Dam. I. McCarley, Robert Winton, joint author. II. U. S. Army Engineer District, Huntington. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper H-77-1)
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